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U. S. S. *NEW HAMPSHIRE.*

DESCRIPTION AND OFFICIAL TRIALS.

BY WILLIAM ASHLEY LEAVITT, JR., ASSOCIATE.

The *New Hampshire* (Battleship No. 25) built by the New York Shipbuilding Company, Camden, New Jersey, is a first-class battleship of 16,000 tons trial displacement, authorized by Act of Congress, April 27th, 1904.

The contract was signed December 27th, 1904; first plate laid May 1st, 1905; hull launched June 30th, 1906; and the vessel delivered to the Government March 14th, 1908, or 16 days over the contract time of 38 months.

Upon delivery of the vessel a considerable amount of work, consisting principally of turret and ordnance details, was unfinished, but as the causes were due to Government changes from original plans, delivery of the vessel to the Government was authorized, the work to be done at the New York Navy Yard.

The contract price for the construction of the hull and

machinery was $3,748,000, of which sum $2,848,000 was allotted to hull and $900,000 for the propelling machinery and auxiliaries. The contract required an average speed of not less than 18 knots per hour for four consecutive hours over a measured course, at a mean draught of 24 feet 6 inches, corresponding to a displacement of 16,000 tons; and an additional endurance run in the open sea, under all boilers, for 24 consecutive hours, at an average of not less than two-thirds of the average horsepower developed on the four-hours' full-power trial. Due to this requirement, in order to minimize the element of risk on the 24-hour trial, it was consistent for contractors to maintain for the four-hour full-power trial a speed close to the minimum contract speed, which was done, but the vessel gave most satisfactory evidences of a fine margin of speed and reserve power when tried out over the measured mile during the standardization runs. The vessel is without any question one of the very best in the United States Navy, and the contractors are deserving of full credit for having turned out such an excellent piece of work.

OFFICIAL TRIALS.

The Navy Department having given permission to begin the official trials December 19th, 1907, the ship left Camden December 15th at 9·30 A. M., but on account of storm, fog, and delay incident to adjusting the compasses, did not clear the Delaware Capes until 2·30 P. M. December 16th, reaching a point off Monhegan Light, 2 hours run from Rockland, Maine, at 10·30 P. M. December 17th, or 32 hours for the run of 480 knots. The trip was devoid of interest except as regards the satisfactory performance of the propelling machinery, the average number of revolutions per minute being 100, except for one hour when a run at 124 revolutions under forced draft was made. This was the only speed run made before the Trial Board took charge and the official trials were made. December 18th was spent at anchor in Rockland Harbor, the Trial Board coming off to the ship in the afternoon for about an hour. December 19th being favorable

both as regards wind and sea, the standardization runs were made over the Government measured-mile course off Monhegan Island, the maximum speed attained being at the rate 20.056 knots, at 125.2 revolutions, developing 19,686 I.H.P.; and the average of the five runs at full power 18.72 knots at 125.22 revolutions, developing 19,652 I.H.P. The only items of note during these runs was a tendency to heat on the part of the F.L.P. port and H.P. starboard crank pins, and these brasses were removed and refitted previous to the four-hour trials.

On December 20th, at 7·15 P. M., the four-hour endurance run in open sea was made most successfully, the course being laid from the lower end of Monhegan Island, S.S.W. ¾ W. along the Atlantic Coast. The most remarkably close engine running was maintained throughout the four hours, the average variation being one-tenth of a revolution. The average number of revolutions for the starboard engine was 118.8; port engine, 118.7; the average of both engines being 118.75, developing 16,772 I.H.P. for the main engines, and a total of 17,267 I.H.P. for all of the machinery; and an average speed of 18.162 knots, the propeller slip being 13.99. The performance was most satisfactory in every respect; and the actual results are as close to the designed as theoretical and practical skill could ever be expected to come. At the conclusion of the four-hour run at 11·15 P. M., in order to make the Delaware Capes on the 24-hour run, time was wasted at slow speed until 5·15 A. M., December 21st, when the 24-hour run began. This run was without incident, and was most successful, the average revolutions being 109.59.

Below will be found general data of the three trial runs in the order mentioned.

STANDARDIZATION.

For the purpose of standardizing the screws thirteen runs were made over the measured-mile course off Monhegan Island, Maine, December 19, 1907, the usual fourteenth run not be made on account of darkness at 4 P. M., making it im-

possible to see the ranges. The weather was clear and cool, with moderate to gentle breeze and smooth sea.

Previous to the starting of the standardization runs the draught was taken and found to be—

Forward, feet and inches	23–06½
Aft, feet and inches	25–07½
Mean, feet and inches	24–06¾
Corresponding displacement, tons	16,071

These runs gave the data from which the curves on Plate I were plotted.

After the standardization run the draught was—

Forward, feet and inches	23–04½
Aft, feet and inches	25–06
Mean, feet and inches	24–05¼
Corresponding displacement, tons	15,976

DATA FOR FOUR-HOUR RUN.

Draught at beginning of trial, forward, feet and inches	23–08⅝
aft, feet and inches	25–09½
Mean draught at beginning of trial, feet and inches	24–08 1/16
Corresponding displacement at mean draught at beginning of trial, tons	16,200
Mean draught at end of trial, feet and inches (11·15 P. M.), estimated	24–07½
Corresponding displacement at mean draught during trial, tons	16,145
Speed of ship, in knots per hour	18.162

	Starboard.	*Port.*
Slip of propellers, in per cent. of their speed	14.02	13.95

PERFORMANCE—FOUR-HOURS' OFFICIAL TRIAL.

Steam Pressures. (*Average of one-half hourly observations.*)

	Starboard.	*Port.*
Maximum steam pressure of boilers, pounds	262.0	
Mean steam pressure at boilers, pounds	246.0	
Maximum steam pressure of engines, pounds, H.P. (chest)	245.0	240.0
Mean steam pressure at engines, pounds	230.0	233.0
H.P. steam chest, gauge, lbs	223.0	221.0
1st receiver (absolute), pounds,	94.0	92.0
2d receiver (absolute), pounds,	33.0	31.4

	Starboard.	*Port.*
Vacuum in condensers, inches of mercury, mean	25.5	25.7
maximum	25.5	26.4

Temperatures. (*Average of one-half hourly observations.*)

Injection, degrees	42.0	42.0
Discharge, degrees	95.0	97.0
Hotwell, degrees	56.0	58.0
Feed water, degrees	163.0	139.0
Engine room, upper platform, degrees	Cool	
working platform, degrees	Cool	
Fireroom, above gratings, degrees	...	
working level, degrees	72.0	
Smoke stacks, average, degrees	...	

Revolutions or Double Strokes per Minute. (*Average of one-half hourly observations.*)

Average revolutions, main engines, per minute	118.8	118.7
Mean revolutions, both engines, per minute	118.75	
Pumps, main air	30.0	28.0
circulating	159.0	145.0
feed, d. s., per minute	34.0	24.6
fire and bilge	46.0	31.0
dynamo condenser, air and circulating	...	...
Dynamos	350.0	
Blower engines	227.4	
Air pressure in firerooms, in inches of water, mean	.49	

Mean Effective Pressures in Cylinders, in Pounds Per Square Inch. (*Averages of cards taken at half hourly periods.*)

Main engines, H.P. cylinder	111.5	111.3
I.P. cylinder	44.7	43.4
F.L.P. cylinder	18.0	18.8
A.L.P. cylinder	18.2	17.5
Mean equivalent pressure, in pounds per square inch, referred to combined area of L.P. pistons	50.4	49.9

INDICATED HORSEPOWER.

Main engines, H.P. cylinder	2,596.0	2,591.0
I.P. cylinder	2,814.0	2,731.0
F.L.P. cylinder	1,497.0	1,566.0
A.L.P. cylinder	1,519.0	1,458.0
total	8,426.0	8,346.0

	Starboard.	*Port.*
Collective H.P. of both main engines	16,772.0	
Air pumps, main	17.0	
Circulating pumps, main	108.0	
Feed pumps, main	201.0	
Dynamo condenser, air and circulating pumps	...	
Fire and bilge pumps	7.0	
Forced-draft blowers	42.0	
Dynamo engines	104.0	
Total for auxiliaries	495.0	
Collective I.H.P. main engines, air, circulating and feed pumps	17,100	
main and auxiliary engines in operation	17,267	

COAL.

Kind and quality used on trial :	Pocahontas hand-picked, excellent.
Pounds per hour, main and auxiliary engines, during trial	29,932

DEDUCED DATA.

I.H.P. (total) per square foot of grate surface	15.7
main engines, air, circulating and feed pumps, per square foot of grate surface	15.54
main engines, air, circulating and feed pumps, per square foot of heating surface	2.73
Pounds of coal per I.H.P. per hour, collective, main engines, air, circulating and feed pumps	1.785
I.H.P. per hour, all machinery in operation	1.773
square foot of grate surface, per hour	27.21
square foot of heating surface, per hour	.635
Cooling surface (main condenser), square feet per I.H.P. (total)	1.221
Heating surface, square feet per I.H.P. (total)	2.728

DATA FOR 24-HOUR RUN.

	Starboard.	*Port.*
Maximum average revolutions per minute for 60-minute period	112.6	112.1
Average revolutions per minute, 24 hours	109.85	109.32
Mean revolutions per minute, both engines	109.59	
Maximum steam pressure at boilers, in pounds	210	
Average steam pressure at boilers, in pounds	192	
Maximum steam pressure at engines, in pounds	196.0	190.0
Average steam pressure at engines	180.1	178.7
Maximum vacuum, each engine	26.6	25.6
Average vacuum, each engine	26.3	25.2
Collective, I.H.P. of all main engines	12,322	

	Starboard.	*Port.*
Collective, main engine, air circulating, feed and hotwell pumps	12,565	
Collective, main and all auxiliary engines in operation during trial	12,715	
Kind and quality of coal used on trial	Pocahontas, run of mine.	
Average pounds of coal used per hour during trial	24,583	
Pounds of coal per hour by main and all auxiliary engines in operation during trial per I.H.P.	1.933	
Pounds of coal per hour used by main engines, air, circulating, feed and hotwell pumps, per I.H.P.	1.956	
Pounds of coal per hour used by main engines alone per I.H.P.	1.994	
Speed of ship, in knots per hour	17.053	
Slip of propellers, in per centum of their own speed	12.60	12.19

INSPECTION AFTER TRIAL.

Summary of Findings of the Board.

Removed all valves of main engines; found same in good condition.

Opened main cylinders and removed rings of H.P. and I.P. pistons; found same in good condition.

Stripped S.H.P. crosshead and P.L.P. and P.I.P. crosshead and found same in good condition.

Stripped S.H.P. and S.A.L.P. crank pins and P.H.P. and forward P.L.P. crank pins. The brasses of S.H.P. and P.H.P. need refitting and S.A.L.P. crank pin needs dressing. The others were found in good condition.

Lifted caps of starboard No. 1 and port No. 4 crank-shaft bearings and found brasses and pins all O. K.

Opened main and auxiliary condensers and filled fresh-water side with water. Found no leakage of tubes, and condensers were clean as far as could be examined.

Opened steam and water ends and valve-chest chambers of main feed pumps; same for one auxiliary feed pump in fire-room. Found everything in good condition.

Opened steam and water ends and valve chambers of main air pumps; found same in good condition.

Opened steam cylinders of circulating-pump engines; found same in good condition.

Opened steam and water cylinders and valve-chest chambers of one fire and bilge pump; found same in good condition.

Emptied all boilers except A, which was in use for auxiliary purposes. Opened steam drums, examined all furnaces, tubes (fire side), inside of steam drums of all boilers, and they were found in good condition. Four-inch tubes above furnaces were generally straight; a few were bowed from $\frac{1}{16}$ to $\frac{1}{8}$ of an inch. Examined also interior of one four-inch tube and four two-inch tubes in all boilers except A. These were found clean and in good condition. A number of grate bars in all boilers were found burned and in bad condition; these require renewal before the ship is accepted by the Government. Steam was on boiler A for auxiliary purposes during the inspection.

Slip joints that were installed on main feed lines near feed-water heaters worked perfectly satisfactory during the trial and were tight.

Examined one blower engine in No. 3 fireroom; was found in good condition.

PRINCIPAL DIMENSIONS OF HULL.

Length between perpendiculars, feet and inches	450–0
on load water line (24 feet 6 inches), feet and inches	450–0
over all, feet and inches	456–04
of straight keel, feet and inches	362–0
Projection forward of F.P., feet and inches	6–04
aft of A.P., feet and inches	0–00
Breadth, extreme, at L.W.L., outside of armor, feet and inches	76–10
molded, feet and inches	76–05$\frac{1}{2}$
Depth, molded, main deck, at side, M.S., feet and inches	43–01$\frac{5}{8}$
upper deck, at side, M.S., feet and inches	50–07$\frac{3}{4}$
Ratio of length to beam	5.94
Displacement per inch, at L.W.L., tons of S.W	63.2
Area of midship section, square feet	1,811
L.W.L. plane, square feet	26,590
wetted surface, square feet	44,000

TANKS.

CAPACITIES OF FRESH-WATER TANKS.

Tank No.	Compt.	Frames.	Location.	Side.	Capacity.		
					Gallons.	S.W.	F.W.
1	...	20-23	Upper Plat.	C.L.	1,250	...	4.6
2	...	20-23	Upper Plat.	S.	3,150	...	11.7
3	...	20-23	Upper Plat.	P.	3,150	...	11.7
4	...	20-23	Upper Plat.	C.L.	2,550	...	9.5
5	...	98-101	Hold	P.	2,550	...	9.5
6	...	98-101	Hold	S.	2,550	...	9.5
1 Res.	...	37-39	Upper	C.L.	1,020	...	3.8
2 Res.	...	72-74	Upper	C.L.	1,020	...	3.8
				Total	17,240	...	64.1

CAPACITIES OF RESERVE-FEED WATER TANKS.

...	B-94	58-61	...	Port	4,937	...	18.3
...	B-95	58-61	...	Stbd.	4,937	...	18.3
...	B-96	61-64	...	Port	4,937	...	18.3
...	B-97	61-64	...	Stbd.	4,937	...	18.3
...	B-98	64-67	...	Port	4,937	...	18.3
...	B-99	64-67	...	Stbd.	4,937	...	18.3
				Total	29,622	...	109.8

CAPACITIES OF FEED AND FILTER TANKS.

...	C-1	80-83	Engine room	P.	5,000	...	...
...	C-2	80-83	Engine room	S.	5,000	...	...
				Total	10,000	...	...

CAPACITIES OF TRIMMING TANKS.

...	A-1	Stem 3	...	P.S.	...	17.6	17.1
...	A-2	3-5	...	P.S.	...	29.3	28.5
...	D-11	101-104	...	P.S.	...	58.3	56.7
...	D-12	104 Stern	...	P.S.	...	39.9	38.8
				Total	...	145.1	141.1

CAPACITIES OF DOUBLE-BOTTOM COMPARTMENTS.

Compartment.	Frames.	Side.	Cu. ft.	Tons.	
				F.W.	S.W.
A-94	12-16	P. and S.	1,690	46.9	48.2
A-95	16-20	P. and S.	2,090	58.0	59.6
A-96	20-23	P. and S.	1,840	51.1	52.6
A-97	23-26	P. and S.	1,960	54.4	56.0
A-98	26-30	P. and S.	2,775	77.0	79.2
A-99	30-35	P. and S.	3,610	100.2	103.1
B-80	35-37	P. and S.	1,720	47.7	49.3
B-81	37-40	P. and S.	2,630	73.0	75.0
B-82	40-44	P. and S.	2,700	75.0	77.0
B-83	43-46	P. and S.	2,735	75.9	78.1
B-84	46-49	P. and S.	2,775	77.0	79.2
B-85	49-52	P. and S.	2,780	77.2	79.4
B-86	52-55	P. and S.	2,790	77.5	79.7
B-87	55-58	P. and S.	2,790	77.5	79.7
B-88	58-61	Port	715	19.8	20.4
B-89	58-61	Starboard	715	19.8	20.4
B-90	61-64	Port	715	19.8	20.4
B-91	61-64	Starboard	715	19.8	20.4
B-92	64-67	Port	715	19.8	20.4
B-93	64-67	Starboard	715	19.8	20.4
C-95	67-71	P. and S.	3,660	101.6	104.5
C-96	71-74	P. and S.	2,674	74.2	76.3
C-97	74-77	P. and S.	2,629	73.0	75.1
C-98	77-80	P. and S.	2,590	71.9	74.0
C-99	80-83	P. and S.	2,520	70.0	72.0
D-96	83-87	P. and S.	2,830	78.6	80.8
D-97	87-90	P. and S.	2,010	55.8	57.4
D-98	90-94	P. and S.	2,440	67.7	69.6
D-99	94-98	P. and S.	2,700	75.0	77.0
		Total	63,228	1,755.0	1,805.2

MAIN ENGINES.

There are two main engines, right and left-hand, outboard turning when going ahead, each in a watertight compartment. They are of the vertical, inverted, direct-acting, four-cylinder, triple-expansion type, designed to develop about 16,500 I.H.P. at about 120 R.P.M., with a steam pressure of 250 pounds at the H.P. cylinder. The arrangement of cylinders, beginning forward, is forward L.P., H.P. and I.P., and after L.P. respectively; the F.L.P. and H.P. and A.L.P. and I.P. being bolted together, thus allowing freedom for expansion between the H.P. and I.P. cylinders in fore-and-aft and vertical planes, while a system of tie rods and

braces prevent fore-and-aft and athwartship motion to the engines as a body. The material used for the cylinders is cast iron, fitted with close-grained, hard cast-iron piston and valve-chest liners, the ¾-inch space between the casings and piston liners being utilized as the steam jacket, the top and bottom heads of the I.P. and L.P. cylinders also being jacketed. Steam for the jackets is taken from the boiler side of the main-engine throttle valve, and passes successively through the cylinders, spring-reducing valves at the I.P. and L.P. cylinders, allowing a maximum steam pressure of 80 and 60 pounds respectively. Each end of the piston valves is fitted with a packing ring of hard cast iron, made practically solid, being turned larger than the bore of the valve-chest liners, cut obliquely, the abutting ends bolted together and finished to fit the liners. The body of the H.P. valve is cast iron, and those of the I.P. and L.P. valves, steel pipe with cast iron heads. The H.P. valve stem is connected to the link block, and the I.P. and L.P. stems to a cast-steel crosshead which is connected to the link block, the Stephenson double-bar link motion, with adjustable cut-off, being used. There are five graduations for points of cut-off on each reverse-shaft arm, and are for the ahead motion only.

The cylinders are supported by a framing consisting of twelve forged-steel columns, 5½ inches diameter, flanged top and bottom for bolting to the cylinders and bed plate; each atwarthship pair of columns being trussed by X-braces, and stiffened fore and aft by horizontal and diagonal tie rods leading from the middle pairs of columns, thus offering no resistance to cylinder expansion.

The crosshead guides, which are of cast-iron, are bolted at the top to facings provided on the cylinders and at the bottom to cast-steel I-section strongbacks carried by the engine framing. The guides, which are of the slipper type, are hollow for the circulation of water to keep them cool.

The bed plates are of cast-steel, made in three sections, flanged and securely bolted together by body-bound bolts.

Each bedplate when assembled consists of two longitudinal and six cross girders of I-section, well stiffened by ribs, and furnishes the seatings for the crank-shaft bearings, engine framing and turning engine. Body-bound bolts secure the bedplates to the keelsons, forged-steel washers being fitted at each bolt between the bedplate and the keelson, the space between the washers being filled in with yellow pine.

The crank shaft is arranged with the cranks 90 degrees apart and is in two sections, the forward L.P. and H.P. being in one, and the I.P. and after L.P. on the other, the sequence of cranks being H.P., I.P., F.L.P. and A.L.P.

The upper ends of the connecting rods are forked for the crosshead brasses; these brasses and those of the crank pin being lined with white metal. Crank shafts and connecting rods are high-grade machinery forgings. The pistons are conical shaped, rough machined all over, the material of the H.P. being cast iron, and that of the I.P. and L.P. cast steel, the followers in each case being of the same material. The pistons are bored taper to fit the rods, and have a square counterbore on the under side to suit the shoulder on the piston rods. Pistons are secured to the rods by steel nuts, locked in place by plates bolted to the piston.

The packing rings are of hard cast iron, being practically solid, having been cut obliquely for machining and the ends clamped solidly together; lugs cast on the back of the rings limit the play, the bore being $\frac{1}{8}$-inch greater than the corresponding bore of the piston.

The piston rods are high grade, and the crossheads and slippers class "A" forged steel, the slippers being faced with white metal. The ends of the rods are tapered to fit the pistons and crossheads, and the slippers are bolted to the crossheads.

The reversing engine is located inboard and is bolted to the top of the H.P. cylinder. There is an oil-control cylinder of brass connected to the steam cylinder by wrought-steel stanchions which serve as crosshead guides. The reverse shaft is also on the inboard side of the engines, near the top

of the engine framing, and is connected to the crosshead of the reversing engine by two forged-steel connecting rods. Differential levers control the valve motion.

The turning engine is located inboard on the after end of the main-engine bedplate. The shaft carries a worm that engages a worm wheel carried by an inclined shaft, at the lower end of which is another worm that engages the driving worm wheel located on the coupling flanges between the crank and thrust shafts. The second worm is keyed to the inclined shaft by means of a feather, but may be moved vertically to engage or disengage the worm wheel on the crank shaft. A square for a ratchet, for turning by hand, has been provided on the after end of the turning-engine shaft.

MAIN ENGINE DATA.

Cylinder Data.

	H.P.	I.P.	L.P.
Diameter, inches	32¼	53	61
Stroke, inches	48	48	48
Thickness of body, inches	1⅞	1 7/16	1 5/16
liner, inches	1¼	1 5/16	1¼
jacket space, inch	¾	¾	¾
valve chest, inches	1 7/16	1½	1½
Number of studs in cylinder covers	36	42	40
Diameter of studs in cylinder covers, inches	1⅛	1⅛	1⅛
Pitch of studs in cylinder covers, inches	4⅝	5	5⅛
Number of studs in valve-chest covers	18	18	16
Diameter of studs in valve-chest covers, inches	1	1	1
Pitch of studs in valve-chest covers, inches	4¼	4⅝	5¼
Number of tap bolts in piston liners	24	36	36
Diameter of tap bolts in piston liners, inch	⅞	⅞	⅞
Pitch of tap bolts in piston liners, inches	4¼	4½	5½
Number of piston valves	1	2	2
Diameter of piston valves, top	17½	19	19
bottom	17 7/16	18 5/16	18 5/16
Diameter of balance pistons, inches	9	9	9
Port area through valve-chest liner, top, inches	159.5	166.92	190.83
bottom, inches	158.7	166.22	190.04
Valve travel, inches	10	10	10

Valve Data for Port Engine.

Steam lead, linear, inches, top	1/16	1/16	1 1/16
bottom	1/16	1/16	1⅛
Full-gear cut-off, top, per cent	81.77	78.12	75.78
bottom, per cent	75.00	70.7	64.49

	H.P.	I.P.	L.P.
Earliest cut-off, top, per cent	58.85	54.68	45.5
bottom, per cent	48.37	46.15	41.5
Diameter of valve stem through gland, inches	2¾	2¾	2¾
valve, inches	1⅝	1⅝	1⅝
Diameter of piston rods, inches	7¼	...	7¼
axial hole, inches	1½	3	4¾
crosshead pins, inches	9½	...	9½
Length of crosshead pins, each, inches	9½	...	9½
slippers, inches	27½	...	27½
Width of crosshead slippers, inches	21	...	21
Lenth of backing surface, inches	27½	...	27½
Width of backing surface, each, inches	7¾	...	7¾
Length of connecting rod, center to center, inches	96	...	96
Diameter of connecting rod, top, inches	7	...	7
bottom, inches	8	...	8
hole, body, inches	1½	3¾	4¼
crosshead end, inches	1½	1½	1½
pin bolts, inches	3	...	3
Number of crosshead-pin bolts	4	...	4
Diameter of crank-pin bolts, inches	4	...	4
Number of crank-pin bolts	2	...	2
Diameter of crank pins, inches	17½	...	17½
Length of crank pins, inches	19	...	19
Diameter of hole in crank pins, inches	10	...	10
Diameter of hole in crank shaft, inches			9½
crank shaft, inches			17½
journals, inches			16½
coupling flanges, inches			28½
Width of crank-shaft coupling flanges, inches			3¼
Number of coupling bolts, each section			8
Diameter of coupling bolts, inches			3¼
pitch circle, inches			23½
Width of crank webs, inches			19
Thickness of crank webs, inches			10¼
Number of main bearings			6
Length of main bearings, H.P., inches			19¼
I.P., inches		19½ and	10¾
forward L.P., inches			19½
after L.P., inches		21½ and	19½
Diameter of main bearing bolts, inches			2¾
Number of main bearing bolts per bearing			4
packing rings in pistons			1
Width of packing rings in pistons, inches			2½
Thickness of packing rings in pistons, inch			1
Number of follower studs in H.P. pistons			10
I.P. pistons			16
L.P. pistons			17
Diameter of follower studs, inches			1½

Reversing Engines.

Diameter of steam cylinder, inches	13
oil cylinder, inches	7
steam-piston rod, inches	2⅞
oil-piston rod, inches	2¾
Stroke, inches	19⅝
Length of connecting rods, feet and inches	3–05⅛
reverse levers, inches	16½
Diameter of reverse shaft, inches	7 and 6
bearings, inches	6½
Length of reverse-shaft bearings, inches	8½

Turning Engine.

Number of cylinders	2
Diameter of cylinders, inches	6
piston rods, inches	1½
valves, inches	3½
Stroke, inches	7
Valve travel, inches	1½
Crank angle, degrees	90
Area of crosshead slipper, inches	16⅝
Diameter of crosshead pin, inches	1¾
Length of crosshead pin, inches	2¾
Diameter of crank pin, inches	2½
Length of crank pin, inches	2½
Diameter of crank shaft, inches	2½
Length of crank-shaft bearings, inches	4 and 3
Diameter of pitch circle of worm, inches	6⅛
wheel, inches	17⅜
Number of teeth	36
Diameter of pitch circle of vertical worm, inches	9
worm wheel, inches	64⅛
Number of teeth	60
Diameter of vertical shaft, inches	4½
Area of step bearing, square inches	38½

ASSISTANT CYLINDERS.

An interesting and important feature of the propelling machinery is the Lovekin Improved Assistant Cylinders, applied to the valve gear of the main engines, this ship being the third in the United States Navy to be equipped with this simple and yet most effective device for overcoming the inertia primarily the cause of considerable wear upon the heavy valve gear working at high speeds with the

resulting item of expense for repairs, and an unnecessary amount of vibration, so annoying at any time and especially so on shipboard.

The highly satisfactory results obtained were anticipated, as the cylinders had proven their usefulness upon the armored cruiser *Washington* and battleship *Kansas* and were the subject of an exhaustive article at that time.

For results obtained upon the *Kansas*, see Volume XIX, No. 2, for the work done by the assistant cylinders on the port H.P. valve gear.

Interested readers will be well repaid by consulting the following references: "Balance Cylinders, Theoretically and Practically Considered," "Performance of the Assistant Cylinders of the *Washington*, and JOURNAL OF THE AMERICAN SOCIETY OF NAVAL ENGINEERS, Vol. XVI, No. 3; XVII, No. 3; XVIII, No. 3, and "The Balancing of Valve Gears, "Journal of the Society of Naval Architects and Marine Engineers," Nov., 1902.

SHAFTING AND THRUST BEARING.

The shafting is arranged in four sections, as follows: Thrust, line, stern tube and propeller, all of Class "A" forged steel. The line and stern-tube shafts are coupled as follows: Two forged-steel collars fit on the end of the stern-tube shaft, secured to prevent turning by four keys, and into a circumferential groove between the collars near the end of the shaft is fitted a pressure ring made in four sections, the coupling bolts passing through the steel collars and the flange on the thrust shaft. The stern-tube and propeller shafts are coupled as follows: The ends of the shafts are joined by a locking ring, over which is a long clamp in halves, each half held in place on the shafts by a longitudinal key, and the two sections of the clamp coupling secured by fitted bolts.

The bodies of the stern-tube and propeller shafts are covered with composition watertight casings; and each outboard coupling is covered with a cast-steel casing filled with melted pitch.

The thrust bearing is of the horseshoe type, with a steady bearing at each end, fitted with glands to prevent the escape of oil. The body is of cast iron, so shaped as to form an oil reservoir, and the horseshoes are of cast steel, made hollow for the oil and water service. They are faced with white metal, and have oil grooves on the bearing surface.

DATA FOR SHAFTING.

Diameter of thrust-shaft, inches	15¼ and 15½
hole, inches	9½
Number of thrust-shaft collars	12
Outside diameter of thrust-shaft collars, inches	24½
Width of thrust-shaft collars, inches	2
space of thrust-shaft collars, inches	4
Length of thrust-shaft bearings, inches	18
Number of thrust shoes	12
Diameter of thrust side rods, inches	3½
line shafting, inches	15½
stern-tube shafting, inches	16½
shaft hole, inches	9½
Length of stern-tube shaft forward bearing, inches	54
after bearing, inches	54½
Diameter of propeller shaft, inches	16½
hole, inches	9½
Length of strut bearing, inches	51
Diameter of thrust-shaft coupling flange, inches	28½
Thickness of thrust-shaft coupling flange, inches	3½
Number of thrust-shaft coupling bolts	8
Diameter of thrust-shaft coupling bolts, inches	3½
pitch circle, inches	23½
Length of collars on stern-tube shaft, inches	3½ and 9½
Diameter of collars on stern-tube shaft (inside), inches	16½
Number of keys	4
Length of keys, inches	14½
Width of keys, inches	2½
Depth of keys, inches	1½
Thickness of pressure ring, inches	1 and 1½
Inside diameter of pressure ring, inches	15
Length of outboard coupling clamp, inches	52
Outside diameter of outboard coupling sleeve, inches	21½
Width of longitudinal keys, inches	2½
Depth of longitudinal keys, inches	1½
Width of locking ring, inches	4
Outside diameter of locking ring, inches	15
Number of bolts	16
Diameter of bolts, inches	2

PROPELLERS.

The hub is fitted on the tapered end of the propeller shaft and held in place by one longitudinal key and a composition nut on the end of the shaft, the nut being threaded the reverse of the direction of the propeller. The nut is locked in place and covered with a composition cap bolted watertight to the hub. The blades fit into tapered recesses in the hub, being held in place by rolled manganese tap bolts, composition chocks being fitted around the bodies of the bolts to keep the blades from shifting after being set to the desired pitch. The bolt holes in the hub are oval in shape and allow a pitch adjustment of one foot either way. The propellers were accurately balanced, and each blade was made a true surface on both faces by machining, grinding and polishing. The material for blades and hubs is manganese-bronze. The spare blades have had the driving faces machined to a true surface by a machine specially designed for this purpose, the backing face being treated as above. The results obtained from a change of blades would be of interest.

DATA FOR ONE PROPELLER.

Number of blades	3
Diameter of propeller, feet and inches	17–03½
Pitch for official trial, feet and inches	18–0
maximum, feet and inches	19–0
minimum, feet and inches	17–0
Ratio of pitch to diameter	1.04
Helicoidal area, square feet	85.68
Projected area, square feet	73.02
Disc area, square feet	234.83
Ratio projected to disc area	.31
Area of immersed midship-section, square feet	1,811.0
Ratio disk to immersed midship-section area	.259
projected to immersed midship-section area	.081
Number of tap bolts for blades	27
Diameter of tap bolts for blades, inches	3½
Length of tap bolts for blades under head, inches	6½
Width of longitudinal key, inches	3½
Thickness of longitudinal key, inches	2½
Length of longitudinal key, inches	35
Diameter of shaft-nut thread, inches	9½
Length of shaft-nut thread, inches	9

Number of threads per inch	4
Immersion of tip of blade, inches	8½
Tip of blade above keel, inches	10

DATA FROM OFFICIAL TRIAL.

	Port.	*Stbd.*
Average revolutions per minute on course	118.7	118.8
Slip, per cent. of its own speed	13.95	14.02

WEIGHTS OF PROPELLING MACHINERY.

The contract weight of the propelling machinery and auxiliaries was 1,500 tons, the actual weight being 1,577.51 tons, or 25.86 tons overweight; thus entailing a loss of $12,930.00 to the contractors if the penalty of $500.00 per ton is enforced. Below will be found the weights in detail and the sum total.

	Pounds.
Cylinders of main engines	266,577
Shafting	187,938
Main-engine framing and bearings	217,276
Reciprocating parts of main engines	72,671
Main-engine valve gear	53,380
Main condensers	92,052
Main, air and circulating pumps	54,497
Propellers	54,346
Boilers	750,120
Boiler fittings	258,573
Smoke pipes and uptakes	335,558
Steam and exhaust piping and valves	104,442
Suction and discharge piping and valves	94,690
Lagging and clothing	46,900
Flooring, gratings, etc	99,737
Auxiliaries	124,702
Fittings and gear	87,740
Water	295,755
Stores, tools and spare parts	172,213
Miscellaneous machinery	164,454
Total	3,553,621

Total weight as above, in tons		1,577.51
Less:		
Contract weight, tons	1,500.00	
Authorized changes, tons	.08	
Spare crank-shaft and propeller blades, tons	16.14	
Water in evaporators and distillers, and feed and filter tanks, tons	35.43	1,551.65
Net weight in excess of contract weight, tons		25.86

BOILERS.

The boilers on this ship are of the Babcock & Wilcox type, and were designed, built and installed by this well known concern. The battery consists of twelve boilers placed two each in six watertight compartments, all compartments being symmetrically arranged.

Each boiler has one drum extending the full width of the boiler and is located within the casings, so that about one-fourth of the shell is in contact with the gases at the top of the combustion chamber. Immediately below the drum are the front headers, and at the back of the boilers are the back headers, connected by tubes set at an angle of 15 degrees.

The weight of the drum and front headers, etc., is carried by the furnace front, and that of the back headers by a light structural-steel girder that also forms a portion of the casing.

This is protected from the fire by a bridge wall of brick extending the full width of the furnaces. There are two of these of equal size, separated by a wall of rectangular water legs that extends from the lower row of tubes to a point just below the surface of the grate. The side walls are similarly constructed, and all are connected to a mud drum carried in the boiler front immediately below and connected to the front headers, thereby providing a constant circulation of water and affording excellent means for draining and blowing off.

The boiler casings are made of steel plates and shapes, fire brick and block magnesia being used for insulation. Front and back at the header space they are in the form of doors of such size that they may be easily removed for access to the inside of the tubes, and the sides are removable in sections for access to the baffle plates and for cleaning soot from the tubes.

Each furnace is provided with three furnace and two ash-pit doors, and the grate bars are of the ordinary common type, of such size and shape as to be handled by one man.

Boiler Drums.—The boiler drums are of open-hearth steel plate, having two seams which are butt-strapped inside and out. The heads are convex, the radius of which is equal to the inside diameter of the drums, and in each is a flanged

manhole shaped from the same plate. All butt straps were formed to the proper curvature of the drum under hydraulic pressure, the rivet holes being punched about $\frac{1}{4}$ inch smaller than the diameter of the rivets used, and then drilled out full size after the plates were rolled and assembled. After drilling, all burrs were cleaned off, the plates reassembled, with turned bolts holding the parts in place for riveting. Wrought-steel pads securely riveted to the drum shell are provided for attaching all valves and fittings.

The following external fittings are provided for each drum:

One 5-inch hand and steam-closing boiler stop valve.

One twin-spring safety valve, each valve $4\frac{1}{2}$ inches in diameter.

Two $2\frac{1}{2}$-inch stop valves for main and auxiliary feed.

Two $2\frac{1}{2}$-inch check valves for main and auxiliary feed.

Two Klinger reflex water gauges with automatic fittings.

One $1\frac{1}{2}$-inch surface-blow valve.

One $\frac{1}{2}$-inch sentinel valve.

One $\frac{1}{2}$-inch air valve.

One $\frac{1}{4}$-inch steam-gauge connection.

Three $\frac{3}{8}$-inch try cocks.

The following internal fittings are provided:

One 6-inch brass dry pipe.

One $2\frac{1}{2}$-inch main feed pipe.

One $2\frac{1}{2}$-inch auxiliary feed pipe.

One $1\frac{1}{2}$-inch pipe and scum pan for surface blow.

Zinc protectors and baskets.

Headers.—The headers are of forged-steel, forged in one piece into a rectangular section, having male and female sinuous side for nesting when assembled. The front side is provided with numerous handholes for access to the generating tubes. The covers for these handholes are of pressed steel, held in place by one stud, nut and dog. All holes for the

generating tubes and connecting nipples between headers and drums are bored and reamed the size of tubing used.

Tubes.—The generating tubes are straight and made of seamless cold-drawn steel. These and the header and drum nipples, which are of the same material, are rolled in place by the B. & W. patent expander. Only one nipple showed any sign of leak on the trial.

DATA FOR BOILERS.

Number of boilers	12
Length of drum, feet and inches	15-03
Inside diameter of drum, inches	42
Thickness of drum plate, inches	$\frac{21}{32}$
Heating surface per header and tubes, square feet	156.8
Total heating surface for one boiler, square feet	3,926.0
grate surface for one boiler, square feet	91.66
H.S. for all boilers, square feet	47,112.0
G.S. for all boilers, square feet	1,100.0
Ratio H.S. to G.S.	42.82
Per cent. of air space in grates	.50
Number of boilers per smoke pipe	4.
Height of smoke pipe above grate, feet and inches	92-11
Area through smoke pipe, square feet	53.46
Ratio G.S. to smoke-pipe area	6.85
Size of generating tubes, inches	2 and 4
Total number of headers, per boiler	25.
Thickness of 2-inch generating tubes, B.W.G.	8.0
4-inch generating tubes, B.W.G.	6.0
Exposed length of generating tubes, feet and inches	9-0
Number of 2-inch generating tubes per boiler	688.
4-inch generating tubes per boiler	53.
Inclination of tubes, degrees	15.0
Height of boiler, feet and inches	13-00$\frac{5}{8}$
Length of boiler, feet and inches	10-01
Width of boiler, feet and inches	14-10$\frac{1}{2}$
Weight of one boiler complete, dry, pounds	62,510
water in one boiler, at middle cock, 59° F., pounds	16,206
one boiler complete, wet, pounds	78,716
Total weight of boilers, dry, pounds	750,120
water in boilers, pounds	194,472
boilers, wet, pounds	944,592
Ratio of weight of boilers dry to boilers wet	.794
Designed working pressure, pounds per square inch	265
Test pressure, pounds per square inch	400

MAIN STEAM LINE.

The main steam pipes are arranged symmetrically in two systems, one on each side of the center-line bulkhead. They are united in the engine rooms by an 8-inch cross-connecting pipe, with a valve worked from both sides of the center-line bulkhead. The main steam pipes are supplied directly from the auxiliary steam pipes by a 7-inch globe valve at the after end of each boiler room, consequently there are no main steam lines in the forward boiler compartments. From the forward and middle compartments the branches unite into a 9-inch pipe, which is increased to 11 inches at the junction of the connection from the after compartment. This diameter is carried aft through the after dynamo room to the engine rooms, passing through the main-engine separators, which are located on the center-line bulkhead in the forward end of each engine room directly under the protective deck. The same diameter is carried from the separators to the main-engine throttle, and between these points a main stop or cut-off valve is located at the separator, and the expansion in this line is taken care of by a balanced expansion joint anchored to the forward engine-room bulkhead. From a 6-inch nozzle on the separators a cross connection is led between the main and auxiliary steam lines. At the separators, nozzles are also provided for 5-inch branches to the receivers, 5-inch bleeder connection to main condensers.

Globe stop or cut-out valves are placed just forward of each junction, and all valves in the main steam line have by-pass valves attached to relieve them when jammed on their seats.

The pipes are of seamless drawn-steel tubing with rolled-steel flanges, the working pressure on the piping being 265 pounds per square inch.

The expansion of the main steam pipes in the firerooms and dynamo rooms is taken care of by an expansion joint in each compartment, and where pipe is bolted to athwartship bulkheads proper allowance has been made for expansion by making bolt holes oval.

When condensed steam is apt to accumulate, drain valves

are fitted and pipes led to automatic float traps, which discharge into condensers or feed tanks.

The piping is lagged with sectional magnesia covering with canvas sewed on and well painted and lagged with galvanized sheet iron.

AUXILIARY STEAM LINES.

The auxiliary steam lines are arranged in two systems, extending fore and aft through the boiler compartments, one on each side of the center-line bulkhead, directly under the main steam line. Each system is supplied directly from the boilers by connecting with the main stop valves of all boilers on its own side of ship through 5-inch branches. From the connection on the forward boiler in the forward boiler compartment the size of the pipe is carried 7 inches to the after end of the after boiler compartment, from which a 4-inch branch is taken on the port side to supply steam to the evaporating plant. Aft of this the pipe is reduced to 6½ inches diameter, and carried 6 inches through the dynamo room to the engine rooms, aft to the 4-inch connection to the dynamo engines, with stop or cut-out valves on the forward dynamo-room bulkhead.

With a valve at the forward engine-room bulkhead the auxiliary steam lines are carried along the inboard sides of the engine rooms, and the two systems are united by a 6-inch connection passing through the center-line bulkhead with a valve at the bulkhead.

Steam to the steering engine is supplied by a 4½-inch branch taken off of the auxiliary steam line in the engine room on the starboard side. The distributing castings in the engine room also supply steam to main feed pumps, main air pumps, main circulating-pump engines, engine-room, fire and bilge pumps, distiller circulating pumps, auxiliary air and circulating pumps, fresh-water pumps, oil pumps, turning and reversing engines, cylinder jackets, after heating system and galley, and connections for blowing out sea chests and boiling out condensers, feedwater heaters and grease extractors.

In the forward fireroom, just forward of the 5-inch connection to the forward boiler, the systems are reduced to 6 inches and fitted with cut-out valves. These 6-inch connections extend to the forward end of the compartment and pass through the center-line bulkhead, with a valve worked from both boiler rooms, thus forming a loop. At this forward cross connection are nozzles for 4-inch steam to dynamos, port and starboard sides; 4½-inch steam to auxiliaries forward of the firerooms, starboard side; 3-inch steam to heating system, port side; 1-inch steam to galley and pantries, port side; 2-inch steam to whistle and siren, port side.

In each boiler room the distributing castings supply steam to the auxiliary feed pumps, fireroom, fire and bilge pumps, blower engines, ash hoists, tube cleaners and connections for blowing out sea chests.

Stop valves are located on the forward side of athwartship bulkheads. The distributing castings are anchored directly to the center-line bulkhead, and the expansion in the pipes and boilers is taken care of by expansion joints, proper allowance having been made for connection on bulkheads by making bolt holes oval.

The material of pipes and flanges is the same as for main steam lines. Where condensation is apt to accumulate, drains are fitted and piped to automatic traps which discharge to condensers and feed tanks.

The pipes are lagged the same as the main steam lines.

MAIN CONDENSERS.

There is one main condenser in each engine room. They are 6 feet 7 inches in diameter by 15 feet 3 inches long by 13 feet between tube sheets. The shell plating is of steel, the water chests of composition, tubes of composition, 70 parts copper, 29 zinc, 1 tin; tube sheets of rolled Muntz metal, and the tube-supporting plates of sheet steel bushed with composition.

The forward water chest, being the one for the entrance and exit of the circulating water, has a division plate on the

center line of the condenser. Sizes of inlet and outlet are 18½ inches in diameter, the inlet nozzle being on the bottom. There are two exhaust nozzles each 22½ inches diameter.

DATA FOR ONE CONDENSER.

Number of tubes	4,816
B.W.G. of tubes	16
Outside diameter of tubes, inch	0⅝
Length of tubes between tube sheets, feet and inches	13-0
Number of supporting plates	2
Cooling surface, measured on outside of tubes, square feet	10,243
Ratio of cooling surface to total heating surface	.388

DATA FROM TRIAL.

	Starbd.	*Port.*
Temperature of injection water, degrees Fahrenheit	42.0	
discharge water, degrees Fahrenheit	95.0	97.0
Ratio of cooling surface to I.H.P. of main engines	1.22	

AUXILIARY CONDENSER.

There is one Davidson horizontal combined air and circulating pump with surface condenser in each engine room.

DATA.

Diameter of steam cylinder, inches	6
air cylinder, inches	10
water cylinder, inches	10
Length of stroke, inches	12
Diameter of circulating-pump suction, inches	5½
discharge, inches	5½
air-pump suction, inches	5
discharge (air pump), inches	3½
Cooling surface of condenser, square feet	553
Number of tubes	441
Outside diameter of tubes, inches	0⅝
Length of tubes between tube sheets, inches	94
B.W.G. of tubes	16

MAIN AIR PUMPS.

The main air pumps are of twin, vertical-beam type, of Davidson design. They are located on the outboard side of the engine rooms, between the main condensers and the feed and filter tank. The discharge is into the filter portion of the feed tank, and there is a 5½-inch cross connection between the suction pipes from the main condensers.

DATA FOR ONE AIR PUMP.

Diameter of steam cylinders, each, inches	12
water cylinders, each, inches	30
Stroke, inches	18
Diameter of steam piston rods, inches	3
air piston rods, inches	3
suction nozzle, inches	11
Diameter of discharge nozzle, inches	9¼

DATA FROM OFFICIAL TRIAL.

	Stbd.	*Port.*
Average stroke, per minute	30.0	28.0
vacuum, inches	25.75	25.5
I.H.P.	17	

MAIN FEED PUMPS AND FEED SYSTEM.

There are two Davidson vertical-piston, double-acting, single, main feed pumps in each engine room, located on the center-line bulkhead forward of the operating platform. The suction is from the feed-tank connecting pipe, and the discharge from the two pumps, after uniting in one 5½-inch pipe, leads forward, passing through a grease extractor, which may be by-passed, and then through the feedwater heater, which also may be by-passed, into the after fireroom, reducing in size as each fireroom is passed.

DATA FOR ONE PUMP.

Diameter of steam cylinder, inches	16
water cylinder, inches	9¼
Stroke, inches	12
Diameter of piston rods, inches	2¼
piston valve, inches	6
suction nozzle, inches	4½
discharge nozzles, inches	4½
Material of water end	Composition.

DATA FROM OFFICIAL TRIAL.

	Stbd.	*Port.*
Average double strokes, per minute	34.0	24.6
I.H.P., per minute	201.0	
pressure on feed main, pounds	315	295

FEED-WATER HEATER.

There is one horizontal feed-water heater on the discharge side of the main feed pumps, on the center-line bulkhead at the forward end of each engine room. The material of water heads is cast steel, and that of the tubes, tube sheets and shell, wrought steel.

DATA FOR ONE HEATER.

Total heating surface, measured on the outside of the tubes, square feet	830.0
Total number of tubes	756.
Outside diameter of tubes, inches	00⅝
Length of tubes between tube sheets, feet and inches	6-09
B.W.G. of tubes	16
Thickness of tube sheets, inches	00⅞

DATA FROM OFFICIAL TRIAL.

	Stbd.	*Port.*
Temperature of feed water, degrees Fahrenheit	163	139
Pressure on feed line, pounds	315	295
Exhaust steam pressure in heaters, pounds	4	5

FEED AND FILTER TANKS.

The feed and filter tank is located on the outbound side of the after end of each engine room. It is rectangular in shape, and at the top is arranged as a filter, the filtering material being "loofa," which is placed between perforated plates, The filtering chamber is divided by vertical division plates. arranged so that the water flows under and over in succession. All material is steel, well galvanized before assembling.

Capacity of each feed and filter tank, gallons	5,000
Total capacity of feed and filter tanks, gallons	10,000

AUXILIARY FEED PUMPS.

In each starboard fireroom, located on the center-line bulkhead, is one Davidson vertical-piston, double-acting, single, auxiliary feed pump. Size of pumps, 12 inches by 8 inches, and 12-inch stroke.

The suctions are from the bottom blows, athwartship compartments, C. and R. pipes from ship's sides (after pump

only), feed suction pipe, reserve-feed water tanks, hose connection. The discharges are to the auxiliary-feed main, main and reserve-feed tanks (after pump only), hose connection, overboard, in port compartment, grate fire extinguisher.

FIREROOM, FIRE AND BILGE PUMPS.

In each port fireroom, located on the center-line bulkhead, is a Davidson vertical-piston, double-acting, single, fireroom fire and bilge pump. Size of pumps, 10 inches by 8 inches by 12 inches.

The suctions are from the bilges, adjacent athwartship compartment, sea, C. and R. drainage manifolds, hose connection. The discharges are to the fire main, overboard in same compartment, hose connection and fire extinguishers.

MAIN CIRCULATING PUMP AND ENGINE.

The main circulating pump and engine is located on the outboard side of the forward end of each engine room. The pump has three suctions, viz: the engine-room bilge, 18½ inches; main drain, 15½ inches, and main injection, 18½ inches. The valves of the various systems are locked in such a manner that only one may be operated at a time.

DATA FOR ONE PUMP AND ENGINE.

Capacity of pump, gallons per minute	12,000	
Diameter of suction nozzle, inches	18½	
discharge nozzles, inches	18½	
impeller, inches	56½	
Width of top of blade, inches	5½	
Diameter of H.P. cylinder, inches	10	
L.P. cylinder, inches	20	
Stroke, inches	10	
Diameter of piston rods, inches	2½	
Length of connection rods, center to center, inches	25	
Valve travel, inches	3	
Angular advance, H.P., degrees	33	
L.P., degrees	34	
	Top.	*Bottom.*
Steam lead, H.P., inch	1/16	1/8
L.P., inch	5/32	3/16
Cut-off, H.P., per cent. of stroke	0.77	0.715
L.P., per cent. of stroke	0.78	0.71

Diameter of H.P. piston valve, inches	4½
Size of L.P. slide valve, inches	1½x19½
Diameter of crosshead pin, inches	3½
Length of crosshead pin, inches	5
Diameter of crank pin, inches	4½
Length of crank pin, inches	6½
Diameter of crank shaft, inches	4½
Length of bearings, inches	5½x8 and 8
Crank angle, degrees	90
Area of crosshead slipper, square inches	60

DATA FROM OFFICIAL TRIAL.

	Stbd.	*Port.*
Average revolutions per minute	159	145
Average I.H.P.	108	

EVAPORATING AND DISTILLING PLANT.

The evaporator rooms are located amidships port and starboard on the berth deck, forward of the engine-room hatches, the distillers being in the ventilator trunk to the starboard room on a level with the main deck.

The plant consists of three evaporators and two distillers, having a designed capacity of 16,500 gallons of potable water in twenty-four hours. The distiller circulating pumps are located in the forward end of each engine room, fresh-water and evaporator feed pumps in the starboard evaporator room.

The evaporator shells and heads are of steel plate, the front steam heads for the coils being of cast steel and the back heads of composition. The tubes are brass, rolled into Muntz metal tube sheets. Each evaporator is provided with steam gauges and relief valves for the shell and coils, also water columns, gauge cocks and blow-off valves.

The distillers are vertical and of the Bureau type. The shell is of cast iron, the covers and tube sheets of composition and tubes of brass, tinned inside and out. The tubes are expanded into tube sheets by rolling, and expansion is taken care of by having the bottom tube sheet made with a flange that works in a stuffing box. The circulating water enters at the bottom, passes through the tubes and is discharged at the top; the vapor enters the shell at a point close to the top tube sheet, the water leaving at a similar point near the

bottom tube sheet. Baffle plates are provided for the inlet nozzles for the circulating water and vapor.

The following pumps of the Davidson type are provided: Two distiller circulating, size 10 by 12 by 12 inches; one distiller fresh water, size 4½ by 5 by 6 inches; one evaporator feed, size 4½ by 5 by 6 inches.

Piping.—Steam for the evaporators and pumps is taken from a reducing valve located in the port evaporator room at the terminus of a branch from the auxiliary steam line. The vapor may be sent to the distillers or the auxiliary exhaust line, the evaporators being arranged for operation in single effect. The fresh water from the distillers passes through a meter into a small reservoir tank located in the evaporator room, from which it may drain by gravity to the main and reserve-feed tanks or may be pumped into these tanks or the fresh-water tanks. The distiller circulating pumps have an independent connection to the sea, and, in addition to discharging to the distillers, may discharge to the sanitary system or fire main.

A test was made of the plant when the ship was at sea December 17th, 1907. First each evaporator and one distiller was given a two-hour trial, and then the entire plant was run for one hour, thereby furnishing an equivalent full-capacity test of three hours. The discharge from the distillers was run into the reservoir tank, and a careful record kept of the number of full tanks. The water was tested for purity at frequent intervals with a solution of nitrate of silver, the concentration of water in the evaporators every half hour, and all other conditions recorded every fifteen minutes. The result of the test of the entire plant proved that better results would be obtained by adding another distiller, which was done after the vessel was delivered to the Government.

The following are the averages of the data obtained from the two-hour test of entire plant:

Steam pressure in evaporator coils, pounds	49.0
shells, pounds	13.0
at reducing valve, pounds	139.0

Pump strokes per minute for entire plant :	
Evaporator feed pump	9.5
Distiller circulating pump	43.5
Output of distilled water in three hours, gallons	2,499.0
Capacity of distilled water in twenty-four hours, gallons	19,992.0

DATA FOR ONE EVAPORATOR.

Heating surface, tubes only, square feet	277.0
Gallons of water evaporated per square foot of heating surface in twenty-four hours	24.05

DATA FOR ONE DISTILLER.

Cooling surface, tubes only, square feet	165.0
Gallons of water distilled per square foot of cooling surface in twenty-four hours	60.58
Gallons of water distilled in twenty-four hours	9,996.0
Temperature of sea water, degrees Fahrenheit	45.0
fresh-water discharge from distillers, degrees Fahrenheit	74.0
external air, degrees Fahrenheit	39.0
evaporator room, degrees Fahrenheit	84.0
Concentration of water in evaporators by hydrometer test, degrees Fahrenheit	$.0\frac{2}{32}$
Quality of water distilled	good
Height of water in evaporators above bottom of glass, inch	1.0

ELECTRIC PLANT.

RECIPROCATING INSTALLATION.

The electric plant in the after dynamo room consists of four 100-kilowatt generating sets (125-volt pressure at the terminals), direct connected to engines of the vertical, cross-compound, double-acting, enclosed type. Generators and engines are of the General Electric Company manufacture.

DATA.

Type of engines	Vertical cross compound.
Number of revolutions per minute	350
Steam pressure, pounds	150
Diameter of H.P. cylinder, inches	10
L.P. cylinder, inches	18
Length of stroke, inches	10
Diameter of piston rods, inches	$2\frac{1}{2}$
Number of generators	4
Capacity of each generator, in kilowatts	100
Dynamos	10 pole, 125 volts.

DATA FOR CONDENSER.

Make	Davidson.
Type, horizontal, combined air and circulating pump, with surface condenser.	
Diameter of steam cylinder, inches	10
air cylinder, inches	14
water cylinders, inches	16
Length of stroke, inches	12
Cooling surface of condenser, square feet	970
Number of tubes	774
Outside of diameter of tubes, inch	$\frac{5}{8}$
Length of tubes, inches	94
B.W.G. of tubes	16

FORWARD DYNAMO ROOM.

Turbo-Generating Installation.

In the forward dynamo room of the U. S. Battleship *New Hampshire* are located two direct-current turbo-generating units. They are of the horizontal Curtis type, and were built by the General Electric Company.

Each unit consists of a 200-kw., 3-stage, 1,700-r. p. m. turbine and a direct-connected 200-kw., 125-volt, 4-pole, direct-current generator.

The turbine is designed to have three stages or pressure divisions. In the first stage there are three rows of rotating buckets and two rows of reversing buckets known as intermediates. The intermediates, however, cover only a small portion of the periphery. In both the second and third stages there are two rows of rotating buckets and one of intermediates.

The steam enters each stage by expanding through a set of nozzles which are designed to give a certain drop in pressure and velocity to the steam entering the buckets. For the first stage the set of nozzles is fastened to the valve casing, and for the second and third stages the nozzles are cast into the stage partitions, or diaphragms, as they are called.

The wheel casing or body of the turbine is cylindrical in form, and all the radiating surface is neatly lagged with Russia iron. The casing is supported on a bed plate which is common to both the generator and turbine.

The wheel, or rotating buckets, are cut out of solid steel

arranged in segments. These segments are riveted to the wheel disc, and are so designed as to size, radius and number as to make a perfect wheel.

For protecting the buckets a steel band is riveted over the outer end, the riveting being done by means of upsetting the end of the bucket.

The wheel disc is riveted to the hub, which is keyed to the turbine shaft.

The turbine and the generator, while mounted on the same bed plate, are two distinct units, each unit having its own shaft supported by two bearings; the shafts being fastened together by means of a flexible coupling.

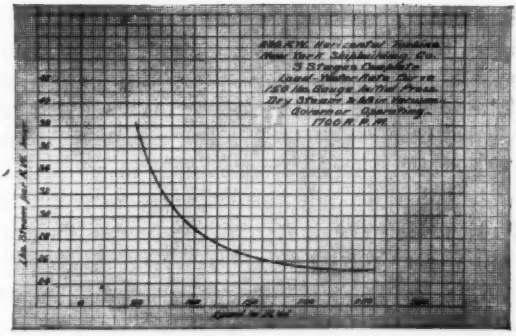
The bearings between the turbine and generator are arranged in one pillow block, and the flexible coupling is also placed in this pillow block, being entirely enclosed by the pillow-block cap.

The turbine shaft is made of nickel-steel, and is designed sufficiently rigid to withstand any tendency to whip which might be caused by excessive water getting into the turbine.

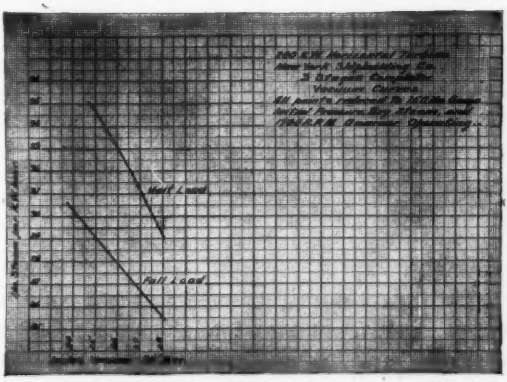
The intermediates or stationary buckets mentioned above are made of a composition metal. Over the inner end of the bucket is riveted, by upsetting the end of the buckets, a steel band for protection. The intermediates extend around the periphery only a sufficient distance to serve in diverting the steam from the nozzles. For instance, in the first stage the nozzles cover an arc of about one-eighth of the circumference of the wheel, and the intermediate buckets cover an arc but slightly longer than the arc of the nozzle.

The total clearance in an axial direction between the wheel buckets and intermediate buckets is sixty-five thousandths of an inch. In a radial direction the clearance is several inches, there being no limit theoretically to this clearance. This large clearance is employed so as to take care of any excessive amount of water which may accumulate in the turbine casing. Besides, there is a large drain box so arranged under the turbine as to drain the water from each and all stages.

For successful operation on high-speed apparatus, such as



LOAD WATER-RATE CURVE, TURBO-GENERATING PLANT.



VACUUM CURVE, TURBO-GENERATING PLANT.

turbines, a good oiling system is necessary. The oiling system for the above turbo-generating set is self-contained and is arranged as follows :

On the turbine end of the shaft is a small worm gear which operates at a moderate speed a small reciprocating oil pump of sufficient capacity to supply oil under pressure to all the bearings. It also supplies oil for operating the hydraulic gear. The pressure can be varied by means of a relief valve, but is generally maintained at about ten pounds per square inch. The oil is pumped from a small reservoir, located in the turbine base, through the bearings, returning through long pipes running the length of the base. The oil in the return pipes is cooled by means of water pipes. By the arrangement the oil is always kept cool, and may be used over and over for weeks without being changed.

The controlling governor is an inertia governor of the spring-and-weight type, and is located at the outer end of the turbine shaft. By means of levers and rods the governor is connected to the hydraulic cylinder, which in turn rotates a cam shaft. Cams mounted on the cam shaft operate successively the valves admitting steam to the various nozzles.

The system of hydraulic operation of the valves is the same as used on all large turbines made by the General Electric Company.

In regard to tests of this unit reference is made to cuts showing complete load curve, giving water rates in pounds per kilowatt hour. Also a vacuum curve at half load and full load, showing improvement gained by increase in vacuum.

The generator end of this unit consists of one armature core on which are two distinct and separate windings, each connected to its own commutator. The commutators are of standard shrink-ring turbine construction, the bars being mounted on a heavy cast-iron shell, this shell mounted directly on the shaft. The shaft is drilled through the center from one end with about a 3-inch hole, which latter furnishes air for the center of the armature core, where are located the ventilating

ducts extending out radially through the punchings. At one end of the shaft is mounted a centrifugal fan, the air from which is directed through the base and thrown directly against the surface of the commutators. This construction admits of using commutators of very moderate size.

Each winding of the armature has a normal capacity of 800 ampères at 125 volts. The two windings are operated in multiple, delivering 1,600 ampères at 125 volts.

There is one series field for compounding, and a commutating field, both of which are wired in series with the main 1,600-ampère load, so that even if slight unbalancing between the two armatures does occur there is proper compounding and compensation effected respectively by the series field and commutating field.

Each commutator is fitted with 11 brushes per stud, 4 studs, and there is mounted on the generator a galvanometer for the purpose of indicating to the attendant whether or not the commutators are dividing the load equally. If the brushes are properly set in the neutral of each commutator and the commutators are kept clean by occasional wiping with a canvas swab, the load will divide practically in halves between the commutators.

CONDENSING PLANT.

The condensing plant consists of one independent air pump, one centrifugal pump and engine and one surface condenser. The performance of the air pump was most satisfactory, on trial a constant vacuum of 26½ inches being maintained running both machines at full load.

DATA FOR AIR PUMP AND CONDENSER.

Make	Edwards.
Type	Vertical, single acting, plunger, flywheel, fitted with a Pickering governor.
Diameter of steam cylinder, inches	5
air cylinder, inches	12
Length of stroke, inches	10
Cooling surface of condenser, square feet	1,600

Number of tubes	1,277
Outside diameter of tubes, inch	00⅝
Length of tubes, inches	94
B.W.G. of tubes, inches	16

DATA FOR CIRCULATING PUMP AND ENGINE.

Capacity of pump, gallons per minute	1,800
Diameter of suction and discharge nozzles, inches	7
impeller, inches	30
Width of tip of blade, inches	1¾
Diameter of steam cylinder, inches	5
Stroke, inches	5

In each dynamo room there is a main dynamo switch board which controls the generators in their respective rooms.

Steam is taken from the auxiliary steam line, and there is a steam separator in each room, which drains to a trap and the steam end of the air pump. The exhaust is into either the dynamo condenser, main or auxiliary condenser or the atmosphere.

Adjacent to each dynamo room there is a distribution room in which is installed a distribution switch board which is energized from either of the two main dynamo switch boards. From the distribution switch boards all the feeders which supply energy to the lighting and power systems are led.

The lighting system comprises a total allotment of 1,250 electric fixtures, not including special outlets for signal lanterns, truck lights, Ardois signal sets and outlets for special fixtures. There are two arc lamps in each of the engine rooms and firerooms.

There are four 30 and two 60-inch searchlights, two 30-inch being installed on the forward bridge, two on the after bridge, and one 60-inch on the searchlight platform on each of the masts. Separate and distinct from the lighting system is the power system, which supplies energy to all auxiliary machinery run by electric motors.

A complete system of wireless telegraphy is installed. Besides the lighting and power system there is an interior communication system, which includes call bells, general

alarms, shrill whistles, fire alarms, voice tubes, telegraphs and indicators.

A system of mechanical telegraph is also installed for communication between the bridge and engine room.

VENTILATION SYSTEM.

Artificial ventilation has been provided for all quarters, living spaces, passages, storerooms and magazines below gun deck, and also for air spaces in wake of boilers, engines and around magazines, for water closets and similar enclosures.

These systems have been arranged in such a way as to keep a continuous circulation of fresh air through the ship, the air being renewed in the various spaces approximately as follows:

Officers' quarters and crew space, berth deck outside of armor bulkheads, in from ten to twelve minutes.

Officers' quarters and crew space, berth deck inside of armor bulkheads, in about four minutes.

Water closets and crews' head, in about six minutes.

Storerooms and passages, in eight to twelve minutes.

Magazines, in from six to eight minutes.

Engine rooms and steering compartments, in about two minutes.

Evaporator rooms, in about two and one-half minutes.

Dynamo rooms, in about three-fourths of a minute.

This ventilation is provided by twenty-five electrically-driven fans, manufactured by the B. F. Sturtevant Company, Boston, Mass. Size, type and location given in table on next page.

The air, as supplied by these fans, running at their maximum speed, has a pressure of 5 pounds to the square foot and a velocity of approximately 2,000 feet per minute.

None of the principal longitudinal or transverse watertight bulkheads of the ship have been pierced by the ventilation ducts where possible to avoid it. No ducts have been carried through the transverse slopes of the protective deck, but in all

Set No.	Capac'y cu. ft. p. m.	Location.			Supply or exhaust.	Type of motor.	Type of fan.
		Deck.	Bet. Frames.	Pors.			
1	6,000	Main	50-51	P.	Exhaust and supply	Enclosed	C. S. P. E. F.
2	6,000	do.	65-66	P.	do.	do.	do.
3	4,000	Gun	8-9	P.	Exhaust	do.	do.
4	600	do.	27-28	P.	do.	Open	C. C. S. E. F.
5	600	do.	65-66	P.	do.	do.	do.
6	600	do.	65-66	S.	do.	do.	do.
7	12,000	do.	74-76	P.	Supply	Enclosed	Double discharge. C. S. P. E. F.
8	12,000	do.	74-76	S.	do.	do.	do.
9	6,000	do.	79-80	P.	do.	Open	do.
10	6,000	do.	79-80	S.	do.	do.	do.
11	4,000	Berth	12-13	S.	do.	do.	do.
12	4,000	do.	21-22	S.	do.	do.	do.
13	4,000	do.	21-22	P.	do.	do.	do.
14	6,000	do.	34-35	S.	do.	do.	do.
15	6,000	do.	34-35	P.	do.	do.	do.
16	6,000	do.	37-38	S.	do.	do.	do.
17	6,000	do.	37-38	P.	do.	do.	do.
18	8,000	do.	71-72	S.	do.	Enclosed	do.
19	8,000	do.	71-72	P.	do.	do.	do.
20	2,500	do.	89-90	S.	do.	Open	do.
21	2,500	do.	89-90	P.	do.	do.	do.
22	4,000	do.	110-111	S.	do.	do.	do.
23	2,500	do.	110-111	P.	Exhaust	do.	do.
24	600	Gun	37-38	P.	do.	Enclosed	C. C. S. E. F.
25	2,500	S. E. R.	99-100	S.	Supply	do.	C. S. P. E. F.

Abbreviations—S. E. R. = Steering-engine room.
C. S. P. E. F. = Convertible steel-plate electric fan.
C. C. S. E. F. = Convertible cast-shell electric fan.

Total, 120,400 cubic feet per minute artificial ventilation.

cases through the flat and fore and aft slopes. Where ducts pass through protective deck they are made watertight to the highest practical point above the berth deck. All ducts passing through magazines are galvanized-steel seamless tubing, or built of heavy-gauge steel worked watertight. A natural exhaust duct, equal to the area of the mechanical supply duct, has been provided for each magazine, and located as far as practicable from the supply duct. The upper ends of these ducts are carried up close to gun deck and inside of the barbettes, where practicable, and terminate there with a goose neck, the lower end of which is bell mouthed and covered with wire mesh.

McCerry, or equally effective adjustable elbows, fitted with butterfly dampers, have been used for supply terminals in all quarters, living spaces and elsewhere. In the quarters they are nickel plated and elsewhere galvanized. All openings of these elbows are fitted with portable wire mesh. All other terminals are stationary.

All cowls have been installed where necessary for fan inlets or exhausts over bakery, galley, etc. Where any of the cowls interfere with the working of the guns, or where necessary for cleaning decks, they are made portable at the weather decks, and where such cowls are too high above weather decks to be easily reached they are fitted with operating gear worked from weather decks. Where required, cowls under awning have been provided with wire-mesh screens.

The ventilation for the coal bunkers has been arranged with ducts of galvanized-steel tubing or built of heavy-gauge material. Valves and dampers have been fitted for this system, and all openings into bunkers have been covered with wire mesh to keep coal out of ducts.

Especial attention has been paid to the ventilation arrangements provided to avoid the transmission of heat from the engine and boiler rooms to other parts of the vessel. In wake of the boiler rooms an air casing under protective deck and on the inboard side of berth-deck coal-bunker bulkheads has been fitted, and connected to the ship's ventilation for supply, and to the funnel casings for natural exhaust. The underside of protective deck within the engine rooms has been fitted with sheathing, with an air space allowed, and connected to the engine-room ventilation system for supply, and to the engine hatches for exhaust.

For ventilating the engine rooms the two fans are arranged to permit one-half the volume of each fan supplying the starboard engine room and the other half the port. Branches have been led from the mains to all working stations, platforms, air casing and corners of the rooms where required for efficient ventilation.

DRAINAGE SYSTEM.

The following is a general description of the drainage system, the features covered being as follows:

1. 15-inch main drain.
2. 5½-inch secondary drain.
3. 4⅝-inch double-bottom drain.
4. 4⅝-inch forward bilge drain.
5. 4⅝-inch aft bilge drain.
6. 4⅛-inch independent drain. (Bu. S. E.)
7. 5-inch independent drain. (Bu. S. E.)

Main Drain.—It is 15½ inches diameter throughout its entire length. It is located on the starboard side close to center line and extends from midway of forward fireroom to forward end of engine room, where it branches and runs athwartship, each branch connecting to a centrifugal pump.

A 15½-inch stop-check valve is located in each fire and engine room, those in starboard fire and engine room being in, and forming part of, main system; the valves in port firerooms being connected through center-line bulkhead to the line in starboard firerooms. All these 15½-inch stop-check valves are operated at valves and on berth deck in deck plates.

In the port engine room, at frame 73, there is a 5-inch connection between the main drain and C. and R. manifold No. 8, located at frame 75-76. This manifold is connected to the fire and bilge pumps in the fire and engine rooms.

Secondary Drain.—It is 5½-inches diameter throughout its entire length. It has connections to all fire and bilge pumps through the C. and R. and S. E. manifolds; also to the handy-billy pump manifold located on upper platform, forward, frames 34-35; after, frames 83-84. The forward connection is made directly to the secondary drain, while the after connection is made through C. and R. manifold No. 9 located in port engine room, frame 82-83.

The forward end connects to C. and R. manifold No. 1, located in port forward fireroom, frames 40-41, and the after

end to C. and R. manifold No. 9 in port engine room, frames 82-83.

The forward bilge drain, forward trimming-tank drain and chain-locker drain are taken by secondary drain through manifold No. 1, located in port forward fireroom, frames 40-41.

The after bilge drain and after trimming-tank drain are also taken by secondary drain through manifold No. 9, located in port engine room, frames 82-83.

There is a 5½-inch connection from bilge well in each fire and engine room to the secondary drain.

Double-Bottom Drain.—The double-bottom drain is divided into three sections, each being 4⅜ inches diameter.

The forward section runs on starboard side between frames 36 and 42, then shifts to port-side, frames 41-42, continues aft, draining double-bottom spaces under fireroom forward of bulkhead 58. It has a connection to C. and R. manifold No. 3, located in central port fireroom, frame 56-57; also to C. and R. manifold No. 4, located in aft port fireroom, frame 65-66.

The central section runs athwartship, frames 63-64, connecting to C. and R. manifold No. 5, located in after starboard fireroom, frame 64-65, and C. and R. manifold No. 6 in after port fireroom, frame 64-65. It drains the double-bottom compartments, outboard of the reserve-feed water tanks. This also has a connection to the forward section at frame 63-64.

The after section runs between frames 70 and 81 through the starboard engine room and drains the double-bottom compartments between frames 67 and 83. This has a connection to C. and R. manifold No. 7, located in starboard engine-room, frame 75-76, which has connection to fire and bilge pumps.

The double-bottom compartments are flooded through the S. E. manifolds connected to C. and R. manifolds by operating the stop-check lift valves in their respective manifolds.

Forward Bilge Drain.—It is 4⅜-inches diameter and drains all the double-bottom ends between frames 12 and 22 (double-bottom ends at frame 12), and the hold compartments between

frames 5 and 12. It connects to C. and R. manifold No. 1, located in forward port fireroom, frame 40-41, and is drained from there through the secondary drain.

After Bilge Drain.—It is $4\frac{3}{8}$-inches diameter and drains all the double-bottom compartments between frames 83 and 98 (double-bottom ends at frame 98), and the hold compartments between frames 98 and 101. It connects to C. and R. manifold No. 9, located in port engine room, frame 82-83, and is drained from there through the secondary.

Independent Drains.—These drains come under the cognizance of Bureau of Steam Engineering. In the firerooms they are $4\frac{1}{8}$ inches in diameter and run from the bilge wells to the fire and bilge pumps. These drains are fitted in each fireroom.

The independent drains in engine room are 5 inches in diameter and come under the cognizance of the Bureau of Steam Engineering. They are fitted in each engine room, and drain the bilge wells in shaft alley and engine room. The drains in the shaft alley connect to C. and R. manifold No. 10 port, No. 11 starboard, frame 86-87, and from there have a direct connection to Bureau of Steam Engineering manifold, which is connected to fire and bilge pumps in engine rooms.

C. AND R. MANIFOLDS—DRAINAGE SYSTEM.

Location.			
No.	Frame.	Port or Starboard.	
1	40-41	P.	In forward port fireroom.
2	47-48	P.	In forward port fireroom.
3	56-57	P.	In middle port fireroom.
4	65-66	P.	In after port fireroom.
5	64-65	S.	In after starboard fireroom.
6	64-65	P.	In after port fireroom.
7	75-76	S.	In starboard engine room.
8	75-76	P.	In port engine room.
9	82-83	P.	In port engine room.
10	86-87	P.	In port engine room.
11	86-87	S.	In starboard engine room.
12	34-35	P.	In passage, upper platform.
13	83-84	P.	In passage, upper platform.

TRIMMING TANKS—PUMPING AND DRAINAGE.

There are four trimming tanks, two forward and two aft.

Those forward are flooded by a 5-inch sea connection, frame 7-6, starboard side. A 3-inch pipe is led to each trimming tank, which is controlled by a 3-inch globe valve, operated at valve and on berth deck in deck plates, frame 5-6.

Those aft are flooded by a 5-inch sea connection, frame 104-105, starboard side. A 3-inch pipe is led to each trimming tank, which is controlled by a 3-inch valve, operated at valve and on berth deck in deck plates, frame 104-105.

Draining.—The forward tanks are drained by a 3-inch pipe led to manifold No. 1, frame 40-41, and the after tanks by a 3-inch pipe led to manifold No. 9, frame 82-83. The extreme forward and after tanks are sluiced into adjacent compartments.

From these manifolds Nos. 1 and 9, water is handled by the secondary drain.

FIRE SYSTEM.

The following is a general description of the fire system.

The fire main is 6 inches diameter and is installed just below protective deck. It runs forward and aft on each side of center line of ship between frame 30-83. At the forward and after end, frame 30-31 and 82-83, the main is run athwartship, thus forming a complete circuit between frame 30-83.

A 4½-inch branch from the forward transverse 6-inch main, frame 30-31, is led forward on starboard side for fire plug between frame 10-30. A by-pass to the flushing system is taken from this branch, frame 17-18. A 5-inch branch is also taken from this 6-inch main on port side, for forward magazine-flooding system.

A 3½-inch branch from the aft transverse 6-inch main is led on starboard side, frame 82-83, to the underside of upper platform and then after to frame 99-100, for fire plugs aft. A 5-inch branch is also led from this 6-inch main on starboard side for the after magazine-flooding system.

There is a 4-inch connection to all fire and bilge pumps in

the firerooms, and a 5-inch connection to fire and bilge pumps in the engine rooms and to distiller circulating pumps.

A 1½-inch branch is fitted in engine rooms at bulkhead 83, port and starboard sides, for flushing stern tubes.

A 2½-inch branch is led from fire-main risers, frame 41-42, gun deck, for flushing ash chutes on main deck, frame 48-49. Also a 2½-inch branch from fire-main risers, frame 60-61, gun deck, for flushing ash chutes on main deck, frames 58-60.

Two relief valves are fitted in the system, one forward frame 14-15 gun deck, and one aft frame 82-83 berth deck; both at 100 pounds.

Cut-out valves for systems and risers below protective deck are operated at valve and on berth deck in deck plates.

All valves in the system are gate valves with indicators.

All hose connections are 2½ inches.

Zinc boxes are fitted in main system about 30 inches apart.

All pipe sizes are internal.

Firemain piping of copper sabined; all fittings of composition.

MAGAZINE FLOODING SYSTEMS.

The following is a general description of piping for the magazine flooding system:

There are two systems—one forward and one aft. Each system floods the magazine spaces in hold and on lower platform; the upper platform systems, forward and aft, being supplied by connections to fire main.

Forward System.—It is composed of two separate systems, one on starboard and one on port side, each being supplied by 8-inch sea connections between frame 21–23.

Adjacent to the sea connections are 8-inch globe valves on lower platform, operated at valves and on berth deck in deck plates.

The systems run below the lower platform beams, branches being led up through the deck to valves in magazine spaces on lower platform and down to valves in hold spaces.

After System.—It is composed of two separate systems,

one on starboard and one on port side, each being supplied by 8-inch sea connections between frame 84–85 and 88–89. Adjacent to the sea connections are 8-inch globe valves on lower platform, operated at valve and on berth deck in deck plates.

The systems run below the lower platform beams, branches being led up through the deck to valves in magazine spaces on lower platform and down to valves in hold spaces.

Upper Platform Systems.—These are connected to the fire main, as described thereunder, and in other particulars have the characteristics of the normal flooding systems.

All magazine flood valves are gate valves, operated at valve and on berth deck in deck plates.

All pipes are of copper, sabined.

All pipe sizes are internal.

Sprinkling Systems.—A sprinkling system is fitted in all magazines, excepting shell rooms and spaces in the hold. It consists, in the magazines, of 2½-inch brass pipe perforated on the under side, so that each powder tank can be sprinkled, and is fitted with cut-out valves in each magazine, operated at valve and on berth deck in deck plates. It is connected with the fire system which serves the flooding system on upper platform, all of which is shown on the plans of the sprinkling system for the forward and after magazines.

All valves are brass gate valves.

FRESH AND SALT-WATER SYSTEMS.

The following is a general description of the fresh and salt-water systems:

Fresh-water Systems.—From the distiller pump the fresh water is discharged to the ripening tanks in after hold, or may be discharged, through a valve with lock, into the tanks forward. From the ripening tanks the water is pumped to the ship's tanks on the upper platform forward by the electric pump aft, and from these tanks may be pumped through the distributing main into the reservoir tanks on upper deck by the forward electric pump. All spaces are supplied with fresh

water from the reservoir tanks by gravity. In case the gravity tanks are out of commission, the forward and after electric pumps are arranged to run continuously, the surplus water being returned to the suction through relief valves in the discharge pipes. The wash rooms for machinists and petty officers, firemen and servants and the laundry are fitted with storage tanks, from which the fixtures are supplied. Other spaces are supplied directly from the main or branches.

For filling the ship's tanks from a dock or water boat, filling pipes are installed between frames 32–33 and 66–67, each fitted with a by-pass to the fresh water main.

Salt-water System.—The sanitary or flushing main is supplied by a direct connection from the distiller circulating pump and a by-pass from the fire system. All plumbing spaces aft of armor bulkhead 28 are supplied by this main.

The spaces forward of armor bulkhead 28 are served by an independent system, supplied by motor-driven certrifugal pumps, which draw from an independent sea valve. This system is also fitted with a by-pass from the fire system.

Deck Drains.—The officers' showers and baths, and firemen's and servants' wash rooms on gun deck, are drained through 4-inch pipes led under gun-deck beams, port side near center line, and discharging overboard through ship's scuppers, frame 42–43, and a special scupper, frame 70–71, port and starboard.

All other plumbing spaces are fitted with independent drains, with the exception of galleys and general mess pantry, which drain through ship's scupper, frame 42–43, port and starboard. The crew's showers on gun deck drain into ship's scupper, frame 9–10, port side only.

HEATING SYSTEM.

The heating system is divided into two sections, one forward and one aft, the forward section being divided into five radiator circuits, two galley and pantry circuits and one laundry circuit; the after section being divided into six radi-

ator circuits and two bath and shower circuits. Steam for radiators is supplied from the auxiliary steam line, the connection at the line being fitted with pressure gauges, stop and relief valves and reducing valves, set at 30 pounds. From this point the steam is carried to distributing manifolds and divided into circuits, as mentioned above, each circuit being arranged with a stop valve so that it can be operated independently of the others.

The galley and the pantry circuits also receive steam from the auxiliary steam line and are fitted with valves and gauges as on radiator lines, but are entirely independent, being constantly under steam. Steam for the laundry is taken from the evaporator shells.

The circuits supply steam to bakery, galleys, pantries, water heaters in bath and wash rooms, and also a coil located in fresh-water tanks to prevent water from freezing.

The drains from radiators are also divided into circuits and lead to receiving manifolds, located forward and aft, each circuit being arranged with a check and stop valve to prevent water from one circuit backing up into another. The discharges from manifolds lead to traps in engine rooms, each manifold having an independent trap, and the drains from these traps are connected together and lead to a drain manifold. This manifold discharges directly to filter tank with a branch on the line located so that it can also discharge to a manifold with branches leading either to the main or auxiliary condensers.

The drains from galleys and pantries lead directly to traps in engine rooms, each section being provided with an independent trap, and these traps discharge to drain manifold mentioned above. The drains from water heaters in bath rooms have no connection whatever with other drains and are carried directly to the auxiliary exhaust lines.

The circuit steam and drain pipes consist of seamless-drawn brass pipe, iron-pipe size, all pipes up to 1½ inches being connected together by composition fittings, but above that size

composition flanges are used. Connections at watertight bulkheads are made with composition stuffing boxes, and copper U-bends are installed throughout the lines to provide for expansion.

Particular care has been taken to prevent water hammer, and as all drains lead downward no pockets have been formed.

The radiators consist of coils made up of 1-inch seamless drawn-brass pipe, iron-pipe size, and composition fittings, stop and air valves.

The stop valves have stems of triangular cross section, valve-stem guards, socket keys for opening and closing, except radiators in officers' quarters, which are fitted with hand wheels. Unions are provided on outlet end of valves, so that radiators can be taken down without disturbing the lines.

Large radiators are divided into sections, each section having an independent steam and drain valve, so that in mild weather it is not necessary to have steam on the entire radiator.

ASH HOISTS.

The ash-hoist engines were designed and built by the Hyde Windlass Company. They are located in the upper hatches, the ventilator trunks containing the bucket guides, ropes and sheaves, etc. The hoist may be operated from either the main or upper decks and are designed to hoist to the upper deck, the bucket-guide rails extending from the bottom of the ventilator trunk to a point well above the upper deck, with trolleys at this deck for delivering ashes to the chutes at the ship's side. On the test 300 pounds were hoisted from the fireroom floor to the upper deck in five seconds, including starting and stopping, with 100 pounds steam pressure.

The hoisting engines are of the reciprocating type, with a rope drum, fitted with a follow-up and reversing gear, and an adjustable safety gear to prevent overwinding and stop the engine when the ash bucket reaches the fireroom floor.

DATA FOR ONE ENGINE.

Number of cylinders	2
Diameter of cylinder, inches	4½
Stroke, inches	4½
Diameter of drum, inches	10
Number of ash-hoist engines in ship	6

FORCED-DRAFT BLOWER.

The forced-draft blowers are located in the firerooms, being suspended from the protective deck about over the center of the stokehold. The engines and fans were designed and built by the B. F. Sturtevant Company.

The arrangement is the same for all of the firerooms, there being one engine, each driving two fans, located athwartship, so that the air is discharged directly to the stokehold floor at a distance of about two feet from the front of the boilers. The supply is taken from the fireroom ventilator ducts, which are closed at the bottom when under forced draft.

DATA FOR ONE BLOWER ENGINE.

Number of cylinders	2
Diameter of cylinders, inches	6
Stroke, inches	6
Diameter of valve, inches	3½
Valve travel, inches	2½
Diameter of piston rods, inches	1 3/16
crank shaft, inches	3 3/16
pins, inches	3½
fan shaft, inches	3 3/16
Length of connecting rod between centers, inches	15½
Number of bearings	5
Total length of bearings, inches	45
Crank angle, degrees	180

DATA FOR ONE BLOWER FAN.

Diameter of fan, inches	66
Number of blades	8
Width of tip of blades, inches	16
Area of induction nozzle, square inches	1,383
eduction nozzle, square inches	2,765

DATA FROM OFFICIAL TRIAL.

Average revolutions per minute	227.4
air pressure in firerooms	.49
I.H.P. for one blower	7
six blowers	42

MACHINE SHOP.

The machine shop is located amidships on the berth deck forward of the after 12-inch barbette and between the machinery hatches, access to it being from the athwartship passage and from the engine rooms through their respective entrance hatches. The machines are arranged with line and counter shaft driven by a 15-horsepower General Electric motor. On a test made to determine whether the motor was sufficiently powerful to do the work, with all machines working on hard cast iron at a heavy cut, 6.21 horsepower was developed.

The following machines are installed:

1 28-inch extension gap lathe;
1 14-inch engine lathe;
1 16-inch crank shaper;
1 31-inch radial-drill press;
1 16-inch sensitive-drill press;
1 30-inch grindstone;
1 Universal milling machine;
1 12-inch emery grinder;
1 combined hand punch and shears;
6 bench vises.

The tools are provided with the most modern attachments, including scroll and drill chucks, index head, automatic cross feed, swivel table, pipe vises, etc., and all necessary tools, drills and cutters.

NOTE.—The writer wishes to acknowledge the receipt of valuable assistance from Mr. Eskel Berg, of the General Electric Company, in the preparation of that part of this article pertaining to the electric plant; and to Mr. J. F. Hunnewell, chief draftsman in the office of the Superintending Constructor at these works, for the description of the pumping and drainage system.

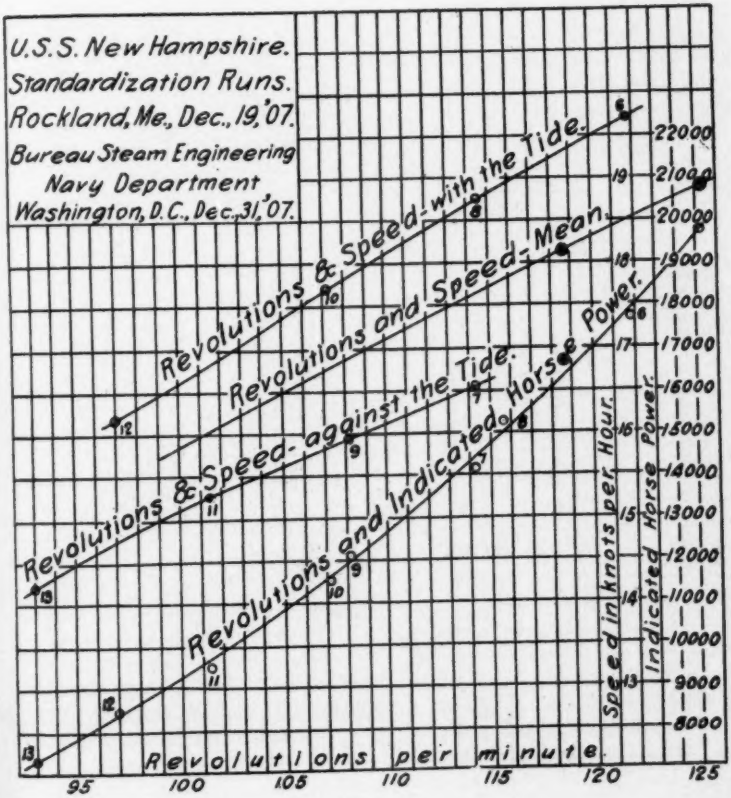
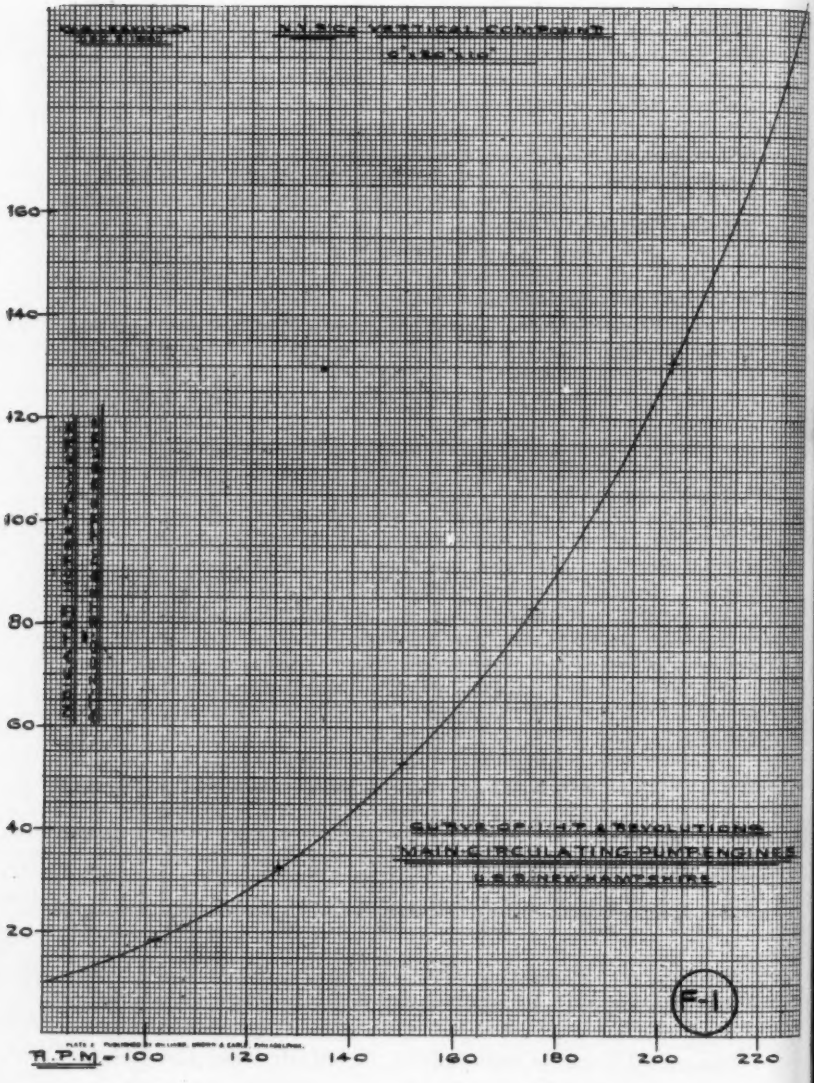
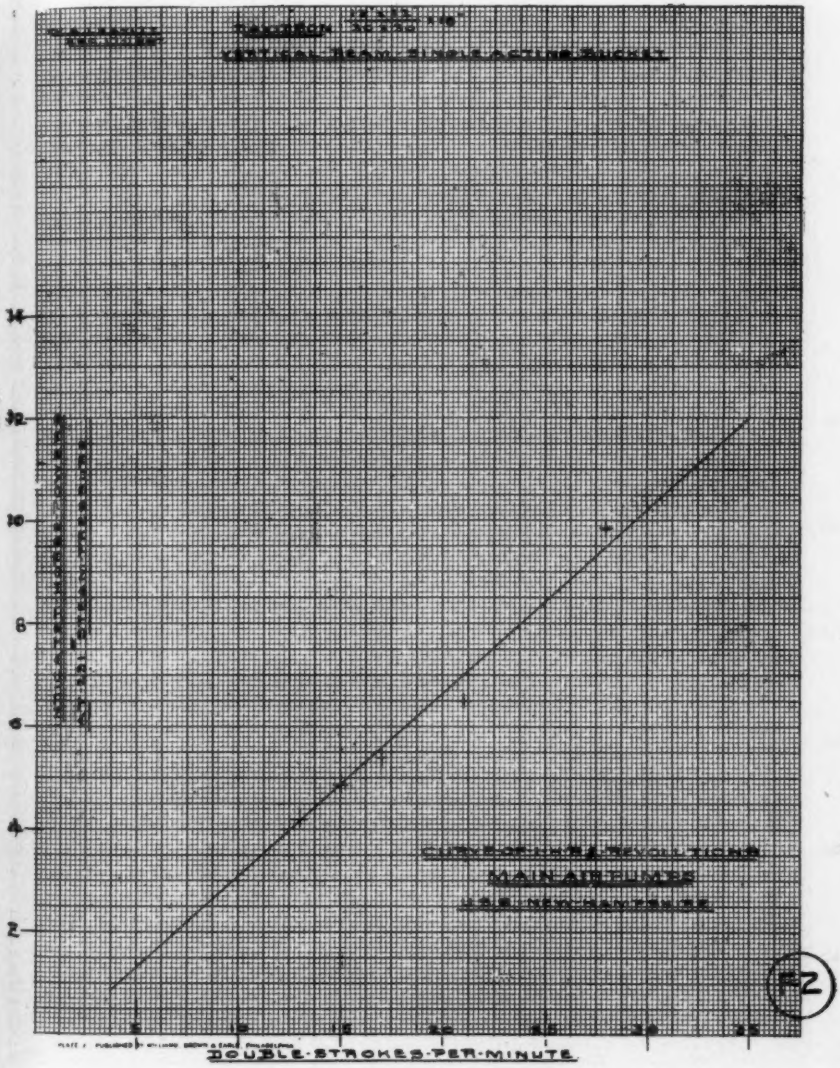
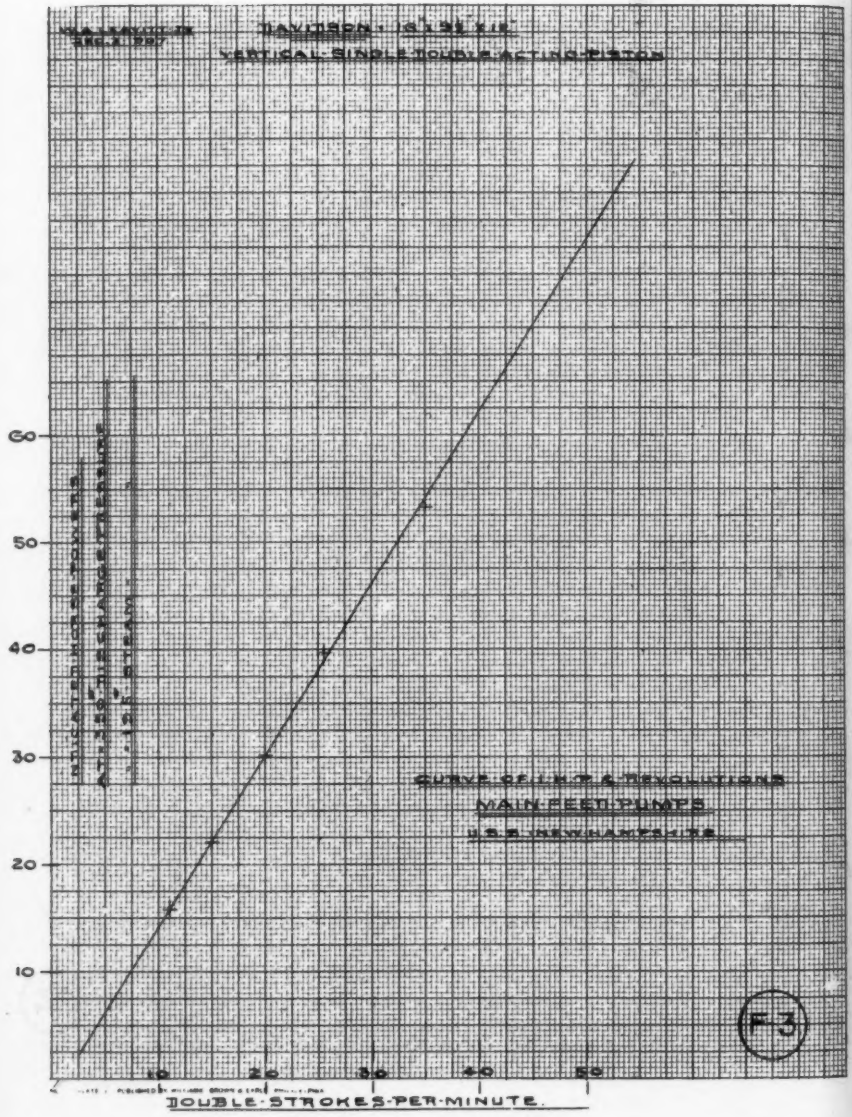
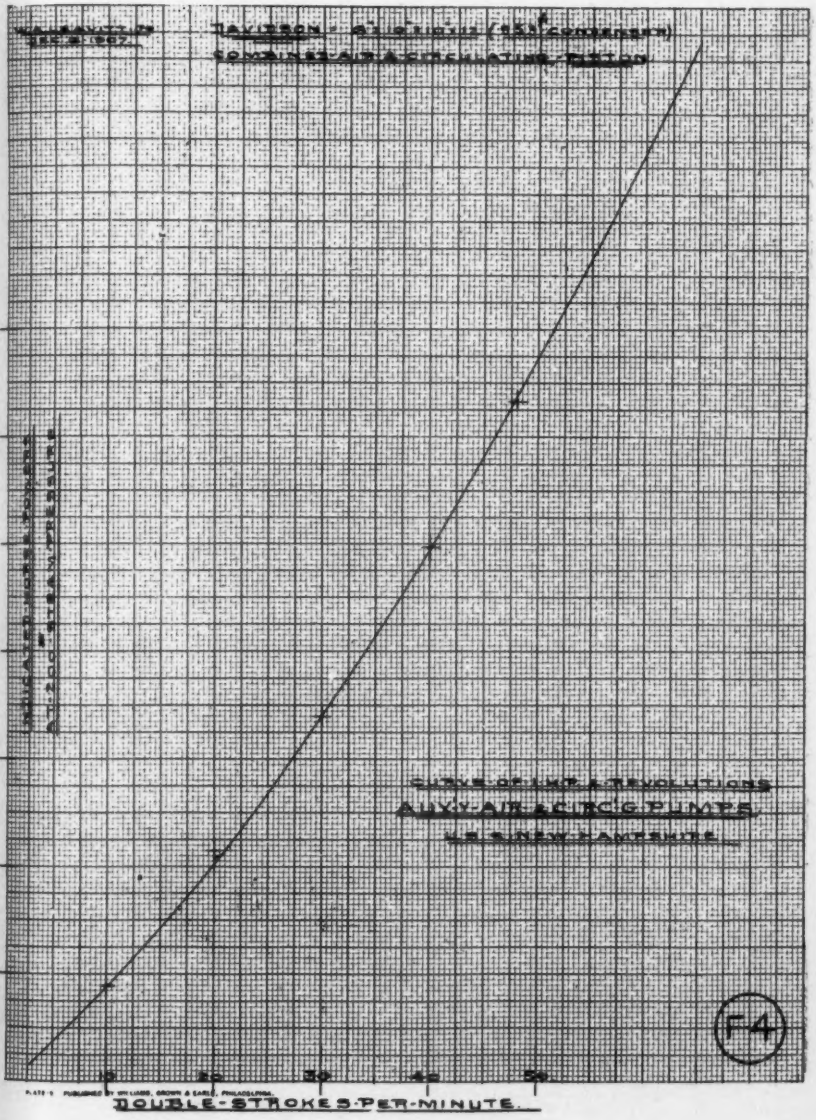

U.S.S. New Hampshire.
Standardization Runs.
Rockland, Me., Dec., 19, '07.
Bureau Steam Engineering
Navy Department
Washington, D.C., Dec., 31, '07.
Revolutions & Speed - with the Tide.
Revolutions and Speed - Mean.
Revolutions & Speed - against the Tide.
Revolutions and Indicated Horse Power.
Speed in knots per Hour.
Indicated Horse Power.
Revolutions per minute.
95
100
105
110
115
120
125
8000
9000
10000
11000
12000
13000
14000
15000
16000
17000
18000
19000
20000
21000
22000

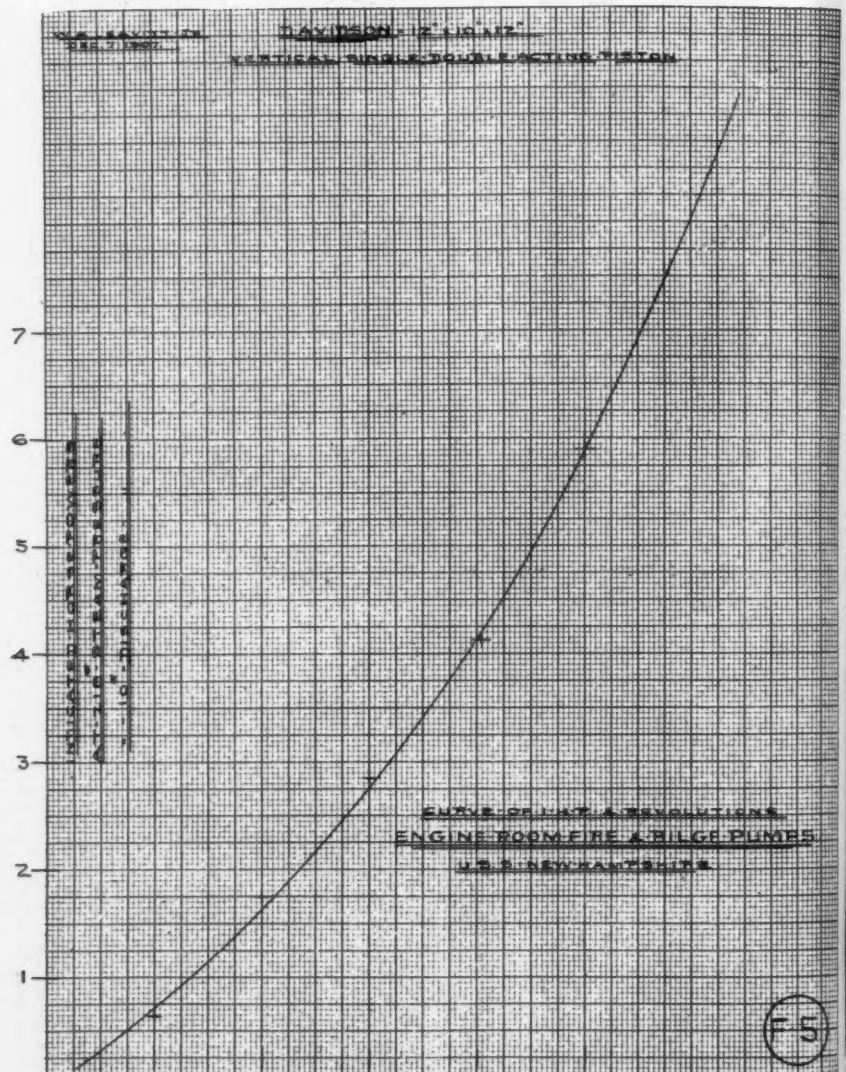
Plate I.


160
140
120
100
80
60
40
20
R.P.M. - 100
120
140
160
180
200
220
CURVE OF 1172 REVOLUTIONS
MAIN CIRCULATING PUMP ENGINES
U.S.S. NEW HAMPSHIRE
F-1


14
12
10
8
6
4
2
DOUBLE-STROKES-PER-MINUTE
MAIN AIR PUMPS
F2


DAVIDSON - 18 1/2" x 18"
VERTICAL SINGLE DOUBLE ACTING PISTON
CURVE OF I.H.P. & REVOLUTIONS
MAIN FEED PUMPS
U.S.S. NEW HAMPSHIRE
F-3
INDICATED HORSE POWER
REVOLUTIONS PER MINUTE
60
50
40
30
20
10
10
20
30
40
50
DOUBLE-STROKES-PER-MINUTE.


TRIAL OF DEC. 2, 1907.
DAVISON - 21 STROKES (95%) CONDENSER
COMBINED AIR & CIRCULATING PUMPS
INDICATED HORSE POWER
ATMOSPHERIC PRESSURE
CURVE OF I.H.P. & REVOLUTIONS
AUX'Y AIR & CIRC'G PUMPS
U.S.S. NEW HAMPSHIRE
F4
DOUBLE-STROKES PER-MINUTE.


DAVIDSON 12" x 10" x 12"
VERTICAL SINGLE DOUBLE ACTING PISTON
CURVE OF I.H.P. & REVOLUTIONS.
ENGINE ROOM FIRE & BILGE PUMPS
U.S.S. NEW HAMPSHIRE.
F.5
1
2
3
4
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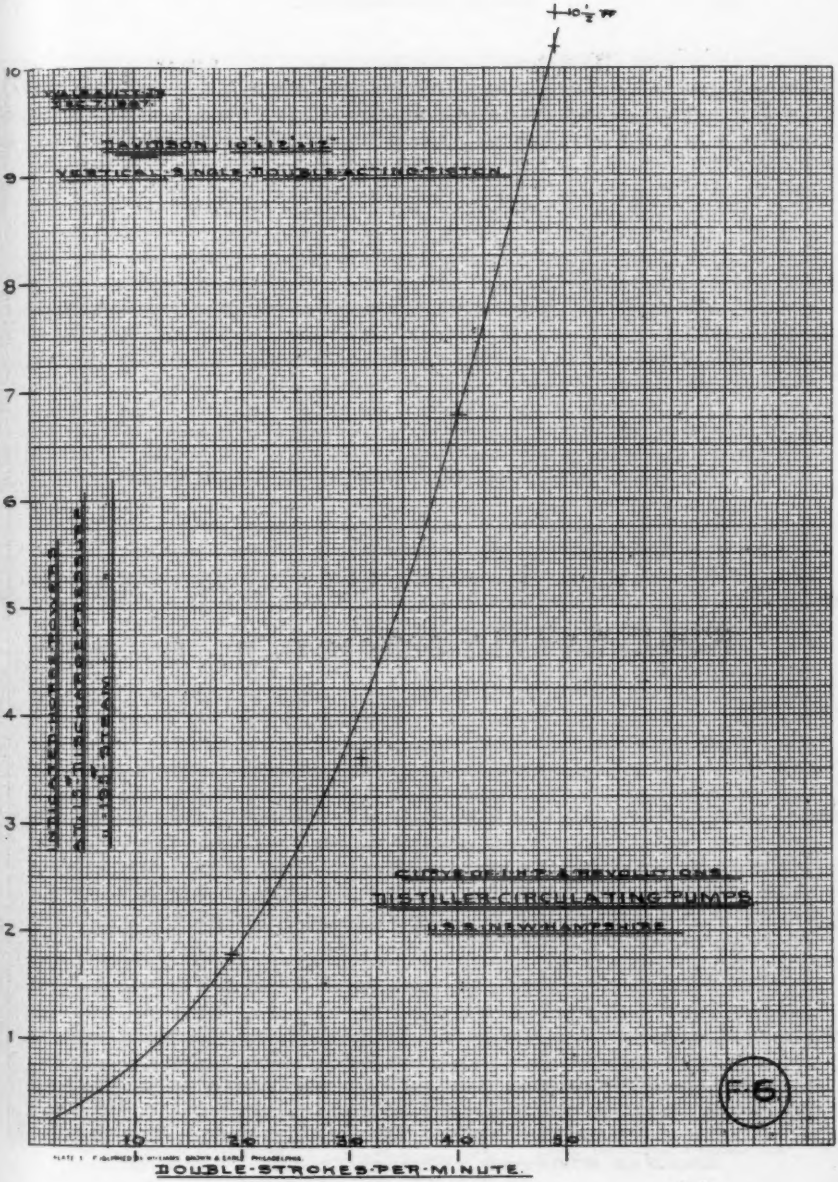
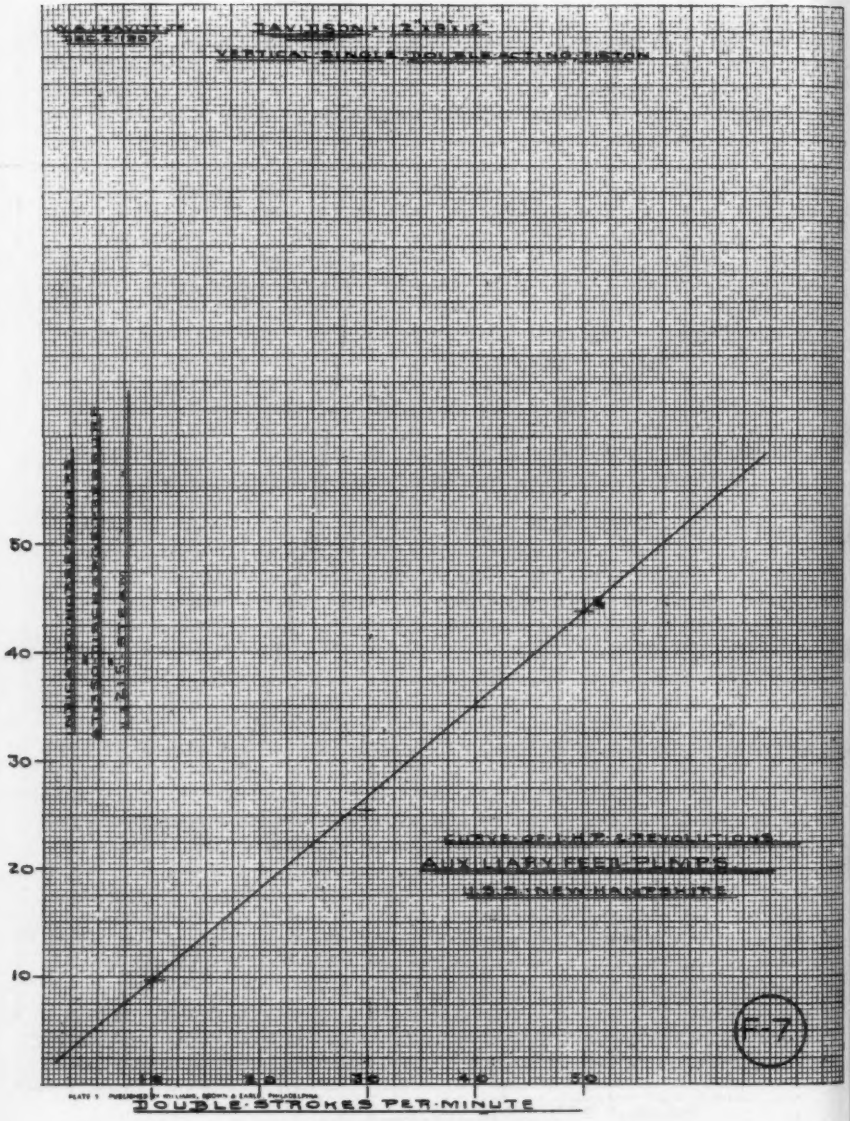
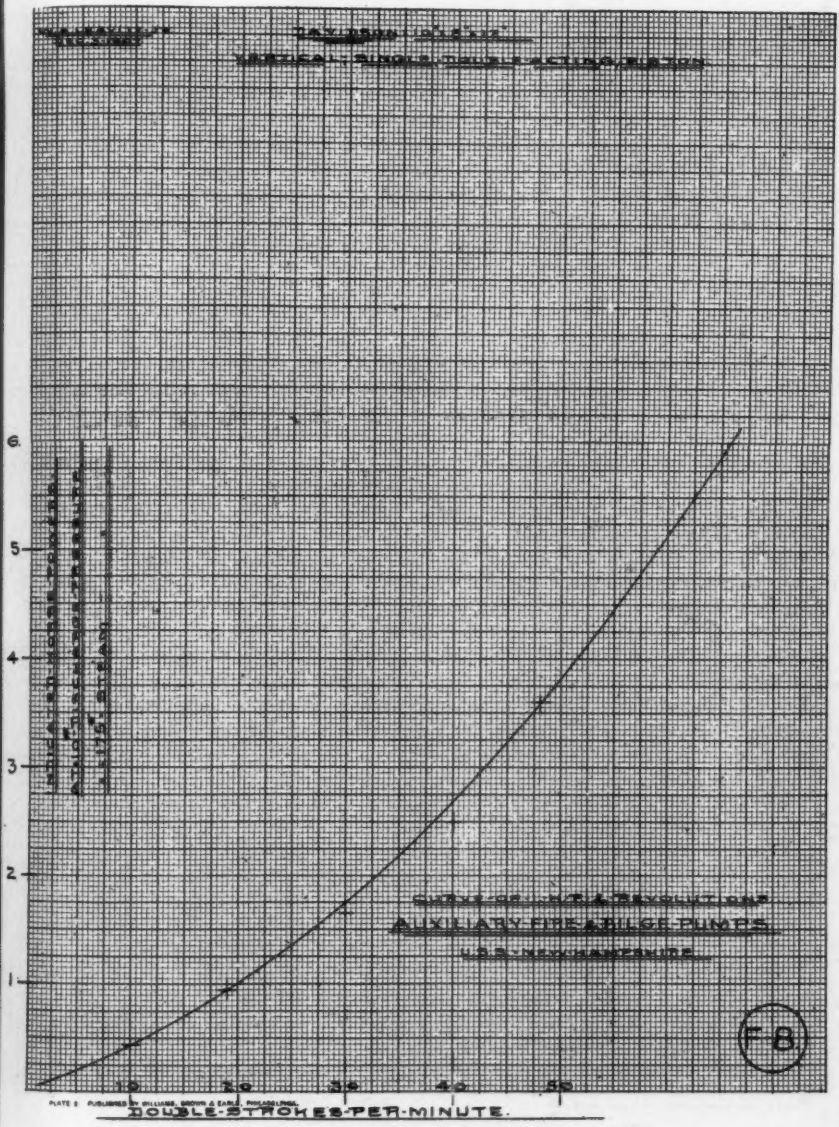
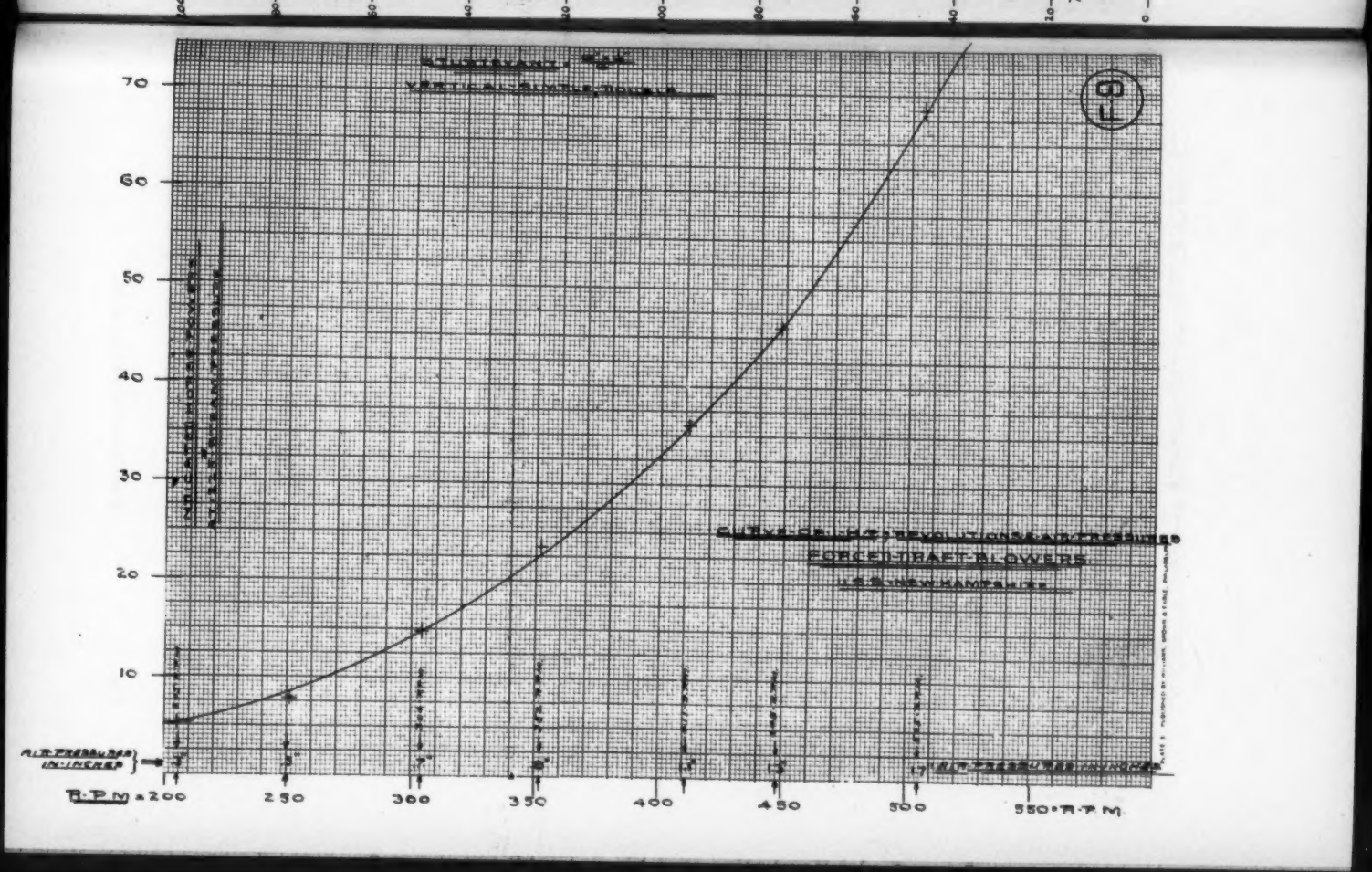
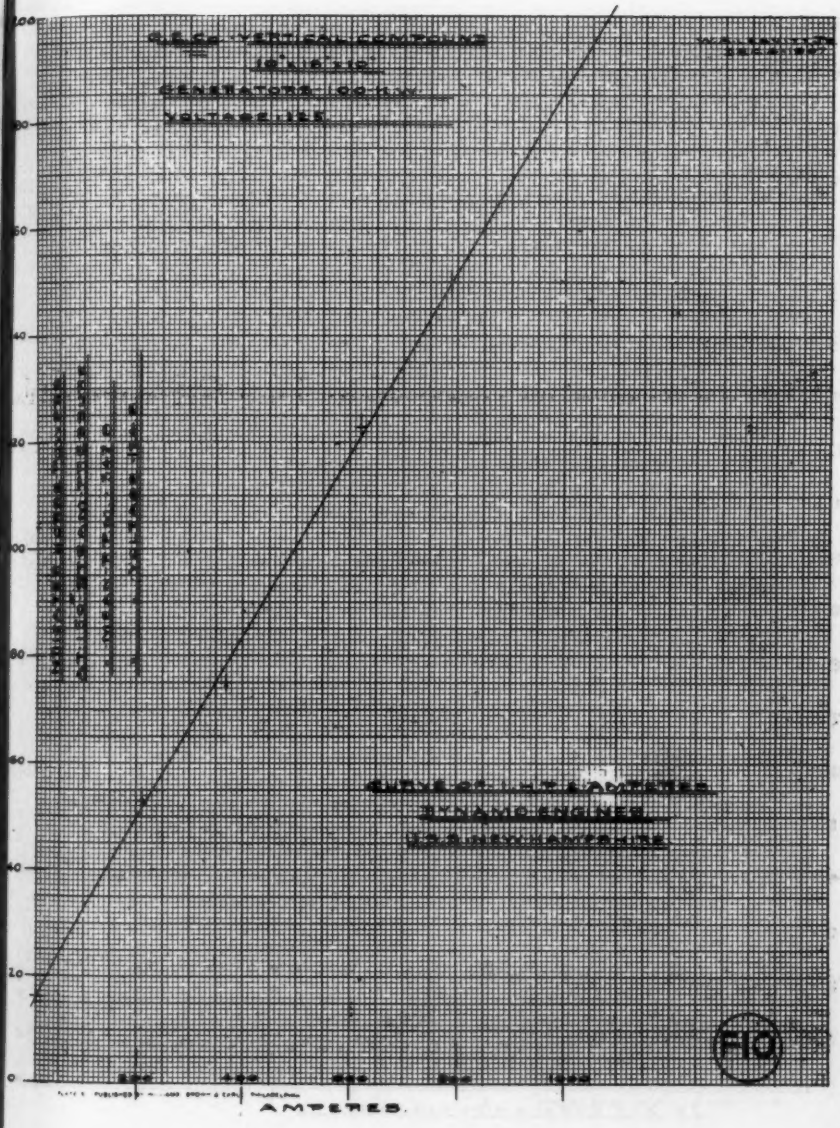
6
7
10
20
30
40
50
DOUBLE-STROKES-PER-MINUTE.

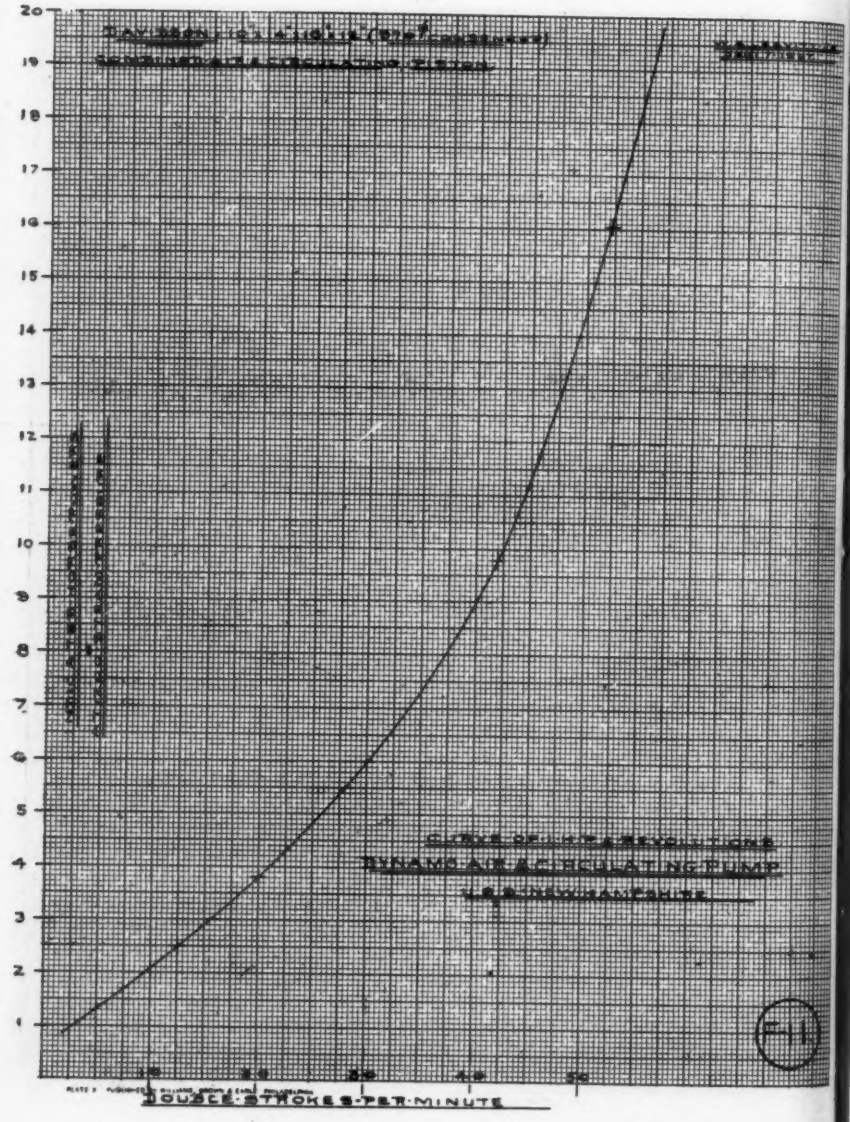

+10½ W
VALVE CUT OFF
TAYLOR-GIFFARD
VERTICAL SINGLE DOUBLE ACTING PISTON
CURVE OF 110 F. A REVOLUTIONS
DISTILLER CIRCULATING PUMPS
U.S.S. NEW HAMPSHIRE
F-6
DOUBLE-STROKES-PER-MINUTE.

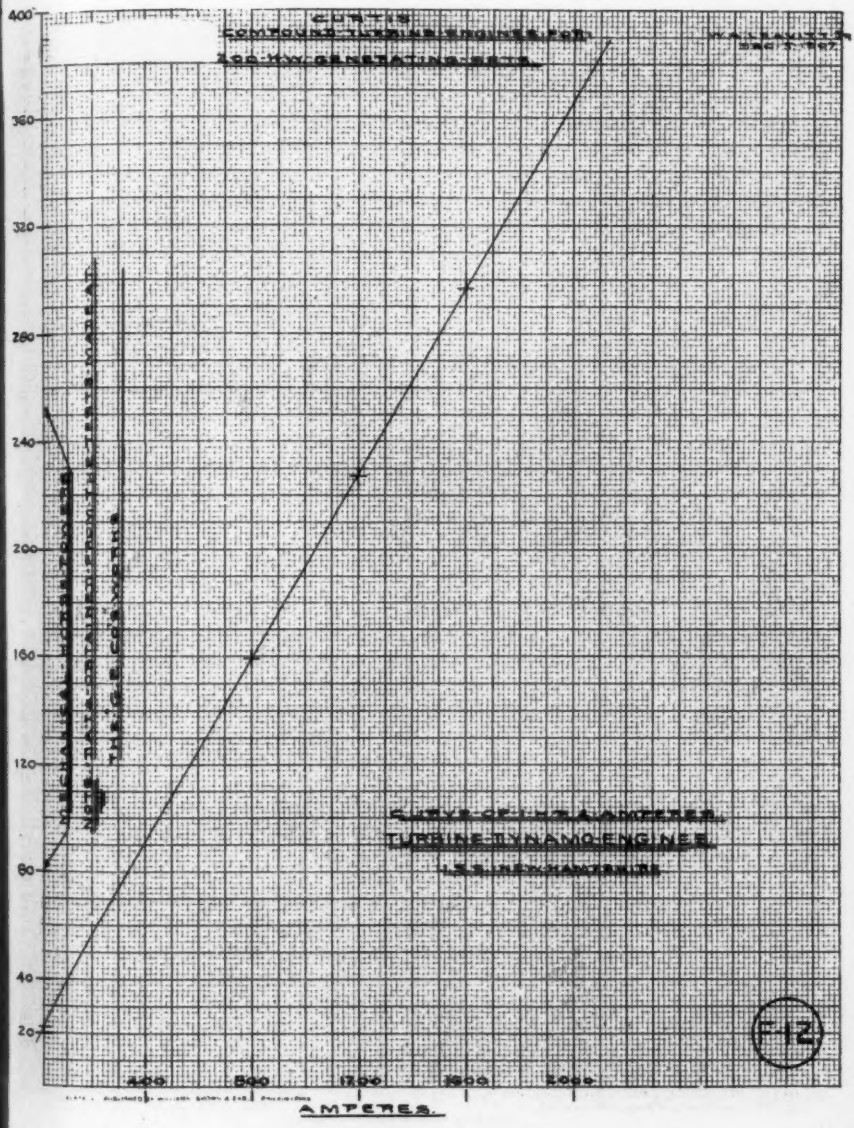

DAVIDSON 12" x 8" x 12"
VERTICAL SINGLE DOUBLE ACTING PISTON
50
40
30
20
10
CURVE OF I.H.P. & REVOLUTIONS
AUXILIARY STEEL PUMPS
U.S.S. NEW HAMPSHIRE
F-7
DOUBLE STROKES PER MINUTE

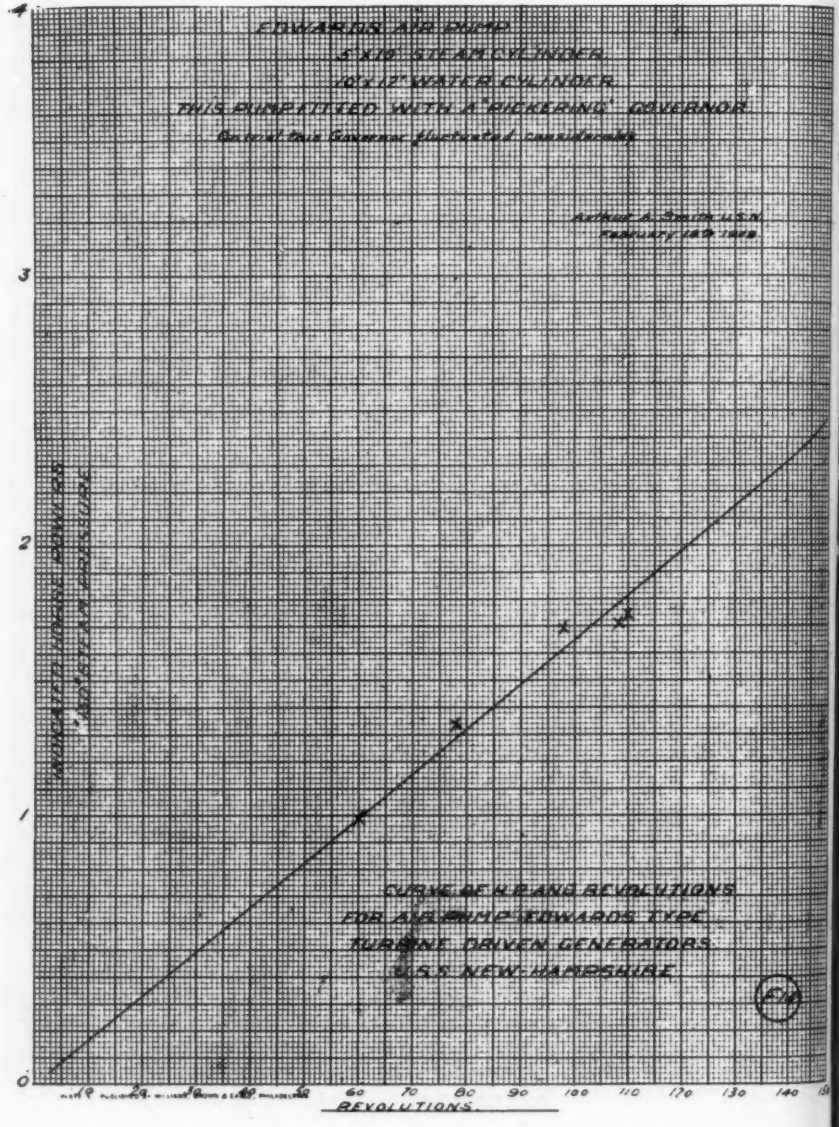

6
5
4
3
2
1
10
20
30
40
50
F-8
DOUBLE-STROKES-PER-MINUTE.

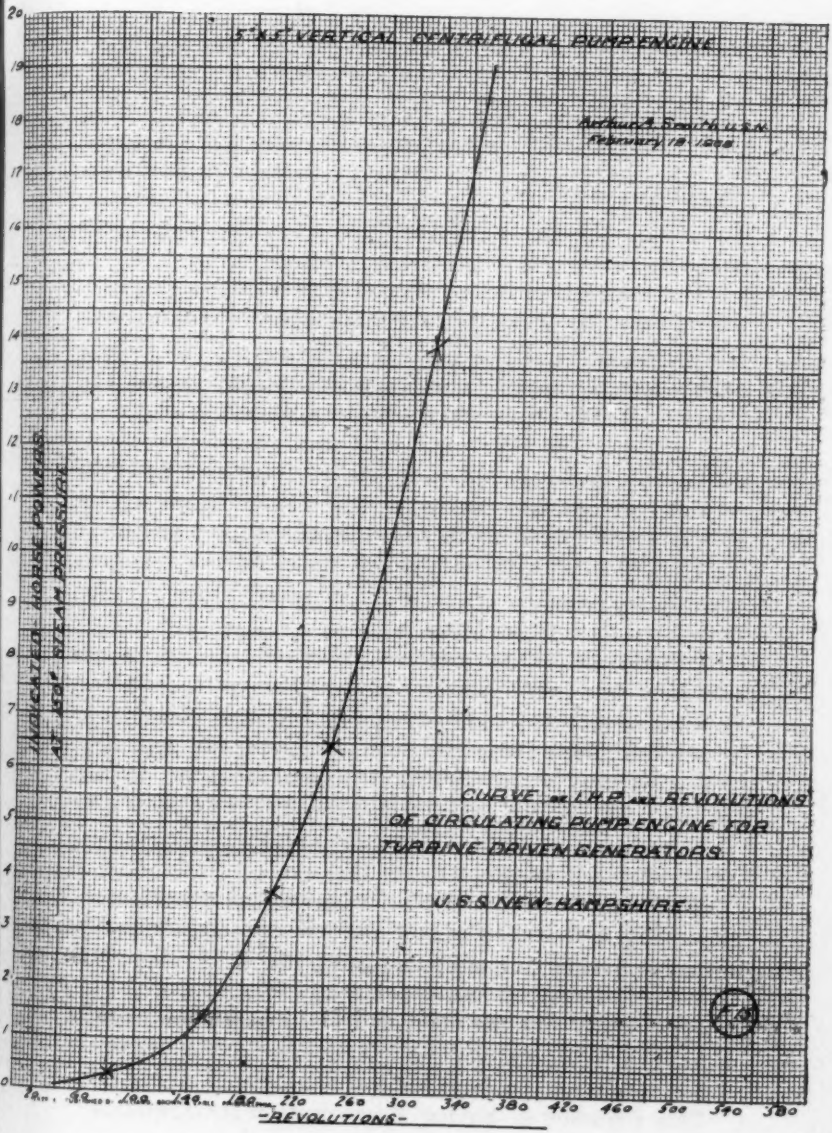

70
60
50
40
30
20
10
R.P.M.
200
250
300
350
400
450
500
550 R.P.M.
FORCED DRAFT BLOWERS
VERTICAL SINGLE INLET


CLASS VERTICAL CONDENSER
ENGINE
GENERATORS 100 K.W.
VOLTAGE 125
CURVE OF K.W. & AMPERES.
DYNAMO ENGINE.
AMPERES.
F10


20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
CURVE OF 1000 REVOLUTIONS
DYNAMO AIR & CIRCULATING PUMP
U.S.S. NEW HAMPSHIRE
F.H.
DOUBLE-STROKES-PER-MINUTE


CURTIS
COMPOUND TURBINE ENGINES FOR
200 KW. OR 1ST STATION SERIES.
W. A. RAUTER
DEC 5 1907
400
360
320
280
240
200
160
120
80
40
20
400
800
1200
1600
2000
AMPERES.
CURVE OF U.S.A. AMMETER.
TURBINE DYNAMO ENGINES.
U.S.S. NEW HAMPSHIRE.
F-12


EDWARDS AIR PUMP
5"X10" STEAM CYLINDER.
10"X12" WATER CYLINDER.
THIS PUMP FITTED WITH A "PICKERING" GOVERNOR
On test this Governor fluctuated considerably
Arthur A. Smith U.S.N.
February 18th 1908.
INDICATED TOTAL POWER
IN BRITISH H.P.
REVOLUTIONS
CURVE OF H.P. AND REVOLUTIONS
FOR AIR PUMP EDWARDS TYPE
TURBINE DRIVEN GENERATORS.
U.S.S. NEW HAMPSHIRE
F.16


5" X 5" VERTICAL CENTRIFUGAL PUMP ENGINE.
Arthur A. Smith, U.S.N.
February 19, 1908.
INDICATED HORSE POWERS AT 150# STEAM PRESSURE.
CURVE of I.H.P. and REVOLUTIONS OF CIRCULATING PUMP ENGINE FOR TURBINE DRIVEN GENERATORS.
U.S.S. NEW HAMPSHIRE.
0
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11
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15
16
17
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19
20
220
260
300
340
380
420
460
500
540
580
-REVOLUTIONS-

SPECIFICATIONS FOR STEAM COAL.

By Civil Engineer A. C. Cunningham, U. S. Navy, Member.

Of all the raw materials extensively and continuously used in the United States, by both the Government and private establishments, probably none have had less supervision and limitation by the consumer than steam coal. Ores of various kinds, lumber, and even sand and gravel are bought under various requirements and limitations, but until practically the present time coal was coal, good, bad or indifferent. It has been bought and used on its reputation, or the reputation and representation of coal dealers, and the consumer has gone placidly on, generally contented, or, when sufficiently discontented, with a change of dealers.

A brief consideration explains this condition. Most raw materials pass into a finished product the quality of which depends upon the quality of the raw material. Steam coal passes into smoke and cinder, and in so doing develops heat. If enough heat is produced to satisfy the consumer, and not too much ash, cinder and clinker to cause him undue trouble and expense, all is well. The most coal he has ever used is his standard; if he keeps inside that amount he is satisfied. The great bulk of coal is used by consumers who naturally have no technical knowledge of the same nor any convenient means of having its quality and value tested. To them "B. T. U." is in the same class as moment of inertia, specific heat, integral signs and the many other things that we use to mystify the ordinary man who has not had the opportunity to dig as deeply into books as some of us.

This condition of buying steam coal on its reputation or

the representation of dealers has begun to change. Many prominent civil concerns have adopted specifications governing the quality of the coal which they purchase, and the Government, through the Geological Survey, is beginning to follow their practice. The intricacies and complications of some of these specifications are interesting, or even amusing, and seem to show a strong influence on the part of the dealer to have the same old coal go as usual. Every one using coal knows that rejections and cancellation of contracts are practically impossible if it is desired to continue business and not shut down a plant for an indefinite period. The coal dealer knows this quite as well as the consumer. In consequence of this condition the important specifications that have been so far used set a standard for the coal that is desired, and then provide a bonus for coal which is better and a fine for that which is poorer. Even the specification of the Geological Survey shares this defect.

Why this bonus and fine in a specification is a defect is as follows: If a steam plant is to produce definite and uniform results a certain minimum quality of coal is necessary to do it; the more nearly a steam plant is worked up to its rated capacity the more apparent does this become; the more nearly it is worked up to its possible capacity the more absolutely certain does it become. Now, if the average quality that is specified is the minimum that is necessary for a plant that is worked up to its rated, or even its possible, capacity, then with any quality below this the plant will not do the necessary work, and everything depending on it will suffer accordingly.

Experience has demonstrated that it will not do to specify the minimum quality of coal that will satisfactorily operate a plant if it is possible for the dealer to furnish anything poorer. It may be necessary or desirable for him to sometimes furnish such poorer coal, and the penalty portion of a specification is very necessary and desirable to encourage him to keep up to the standard established.

Why the bonus portion of a coal specification is a defect is

as follows: In no class of raw material, or material which is to be re-worked, is an average quality specified. A minimum quality is set, and it is safe to leave it to the dealer that nothing much better than this will be furnished. This is true of ores, lumber, cement, iron and steel, provisions and everything that can be readily named. The reason for this minimum quality in re-worked material is apparent, for if it were not for this rule some parts of the finished product would be poorer than others, as in a boiler, a building or a line of pipe, and we are brought to the condition which has produced the maxim that "the strength of a chain is the strength of its weakest link." Why we endure an average quality in a coal specification is due to several reasons. Coal specifications are new, and we have used and endured an average quality for very many years; the coal dealer has some influence and weight with us in his trouble; we do not turn the coal into a finished product, and there are no apparent or enduring results from using an average, or partly good and partly poor coal. Thus when we allow a bonus on coal we are not improving the quality except by paying extra for it, and even then the improvement of quality is at the mercy of the dealer and not the consumer.

When detailed to duty at the Norfolk Navy Yard, the author was confronted by a "condition and not a theory" on the question of steam coal. This yard has always been a natural market for Pocahontas coal, and such had been specified without further qualification. Keen competition, however, succeeded in eliminating "Pocahontas" from the specification and substituting definite requirements for the constituents of the coal. A foreign coal took the contract and trouble immediately began. The requirements for the coal were not met, and as the specification provided for no penalty, the steam plant became "the sport of circumstances." The contract was finally canceled and relet under an improved specification containing a penalty provision. The contract was taken by the same parties who furnished the unsatisfactory coal at an advance of only seven cents a ton,

and coal equal to the average of Pocahontas was thereafter supplied. This experience led to a considerable study of the coal question and how to control it, and it is believed that the following specification is simple, reasonable and just; that it will produce a fair competition and restrain the bidder from offering goods that he cannot deliver.

The limitations in the specification are liberal for such coal as would naturally reach the Norfolk market, and the general quality is not the lowest that could be used under usual conditions; occasional failure on the part of the contractor would not produce serious conditions, and the extra labor and coal, due to a failure, would be compensated for.

SPECIFICATION FOR COAL.

(1.) Coal shall be of steaming quality, bituminous or semi-bituminous, run of mine, and as free from deleterious and objectionable matter as consistent with the best mining and transportation practice.

(2.) Payment shall be made on the weight of coal as delivered to the consumer.

(3.) Representative samples, selected from the coal as delivered to the consumer, shall, on laboratory test, not exceed the following limits of the substances named:

Moisture, per cent.	1
Volatile matter, per cent.	22
Sulphur, per cent.	1
Ash and solid matter, per cent.	7

(4.) Bidders shall state in their proposals the least calorific value of the coal they propose to furnish, when dried, in British thermal units per pound of coal. The calorific value named in the accepted proposal shall form part of the contract, and tests will be made for same on dried coal from representative samples of the coal as delivered. Coal falling short in calorific value of the standard established by the accepted bid shall be reduced proportionately in price.

(5.) For each one whole per cent. of moisture on laboratory test in excess of the limit named, there shall be deducted 1 cent per ton from the contract price of the coal.

(6.) For each one whole per cent. of ash and solid matter on laboratory test in excess of the limit named, there shall be deducted 1 cent per ton from the contract price of the coal.

(7.) For each whole half per cent. of sulphur on laboratory test in excess of the limit named, there shall be deducted 1 cent per ton from the contract price of the coal.

(8.) For each one whole per cent. resulting from the addition of the excesses of moisture, sulphur, ash and solid matter, or any two of them, when below the deduction limits named for each separately, on laboratory test, there shall be deducted 1 cent per ton from the contract price of the coal.

(9.) Tests for calorific value shall be made with a bomb calorimeter, and all laboratory tests in accordance with the latest approved methods of the American Chemical Society.

(10.) The contractor, or his authorized representative, may have the privilege of witnessing the weighing, sampling and analysis of coal, provided that no undue delay is caused thereby, or the user may have the same verified by a competent and responsible person; but in any event the weighing, sampling and analysis made upon the delivery of coal shall be final.

(11.) Failure of the coal to comply with the specified requirements and original limitations shall be sufficient cause for rejection or cancellation of the contract.

The foregoing specification is the outcome of the author's endeavor to secure good steaming coal, the result of the study of available literature and specifications and the observation of the working of coal in connection with its analysis. A translation of the specification will be next in order:

Steam coal may be anthracite, semi-bituminous, bituminous or peaty in its nature; local conditions and available supply will determine which is used, but bituminous and semi-bituminous are by far the most largely and widely used, and the actual difference between them is sometimes small. "Run

of mine" coal is generally accepted to mean coal that contains not less than forty per cent. of lump, no lump of less dimensions than a three-inch cube. Coal may leave the mine in this proportion, but in successive handlings may become so broken up as to generally resemble "slack" in fineness. It has not, however, lost any of its original quality, and if it passes all tests and fires satisfactorily no exceptions need be taken to the proportion of lump, which is hard to ascertain at the best.

Other classifications of coal are as follows: "Lump," in which not over ten per cent. is of a size the equivalent of a three-inch cube, and the balance greater; "Egg" or "Nut," in which not over ten per cent. is of a size equivalent to a one-and-a-quarter-inch cube, and the balance in larger sizes, but not exceeding the equivalent of a three-inch cube; "Steam Nut," in which not over ten per cent. is of a size equivalent to a half-inch cube, and the balance in larger sizes but not exceeding the equivalent of a one-and-a-quarter-inch cube; "Slack," which is everything under the equivalent of a half-inch cube, including dust, slate, dirt and any other objectionable or deleterious matter that may be present.

These classifications are not universal or rigid; they are applied to the coal at the mine, and subsequent handling and transportation may produce conditions which are intermediate to the original ones, and also more or less fine coal, sometimes wrongfully called "slack." From a consideration of these classifications it will be obvious that "run of mine" will be the cheapest coal of good quality for general steaming purposes.

The principal objectionable and deleterious matters that occur in coal are the various natural combinations of sulphur, slate, crop coal, white scale and bone coal. Crop coal is that part of the vein that has been exposed to the weather. White scale is carbonate of lime and an adulterant. Bone coal is a portion of the vein that is intimately mixed with fine slate or clay. All deleterious and objectionable matters are fairly visible to a trained eye and should be separated from the coal at the mine.

The weight of coal as delivered to the user will vary with the amount of moisture it has given up or absorbed from the time it has been mined until it is delivered. It may come from the mine wet and drain out or dry in transportation, or it may come from the mine dry and absorb moisture from exposure to rain and snow in transit. In well-handled and transported coal the moisture will usually vary from one-half of one per cent. to one per cent. In a test on a twenty-pound sample the author found that about five per cent. of moisture could be carried without dripping. It is necessary to limit the amount of moisture that will be accepted, in order to insure careful handling and transportation. It is sometimes thought that moisture improves the burning and heating value of coal; for those who think so it is better to add the moisture and not pay from three to five dollars a ton for it. It seems hardly necessary to say that moisture not only has no heating value, but uses up a certain amount of otherwise effective coal in evaporating it.

A representative sample selected from the coal as delivered should contain as nearly as possible the same proportion of lump, fine coal and dirt as the shipment. By selecting from various depths it may also be taken so as to contain about the average percentage of moisture. Analyses made on lump coal only will show very much better results than an average sample, and analyses made on fine coal only will give poorer results than the average. The reason is obvious, as the lump coal comes from the purest and most solid part of the vein, and is largely free from slate, dirt and sulphur compounds. The fine coal, on the contrary, is mixed with the deleterious and objectionable substances. Many specifications give elaborate directions for pulverizing, quartering and re-quartering the sample for analysis. It is important that the sample should be representative of the general and average condition of the coal, and that it should be placed in fairly tight receptacle to prevent the evaporation or absorption of moisture; these precautions being taken, the chemist can be depended upon for further details.

The volatile matter in coal is generally and principally hydrogen, oxygen and nitrogen, and in proportions of from 15 to 20 per cent.; the approximate relation of these elements is about 5 hydrogen, 4 oxygen and 1 nitrogen. The volatile matter has no practical heating value.

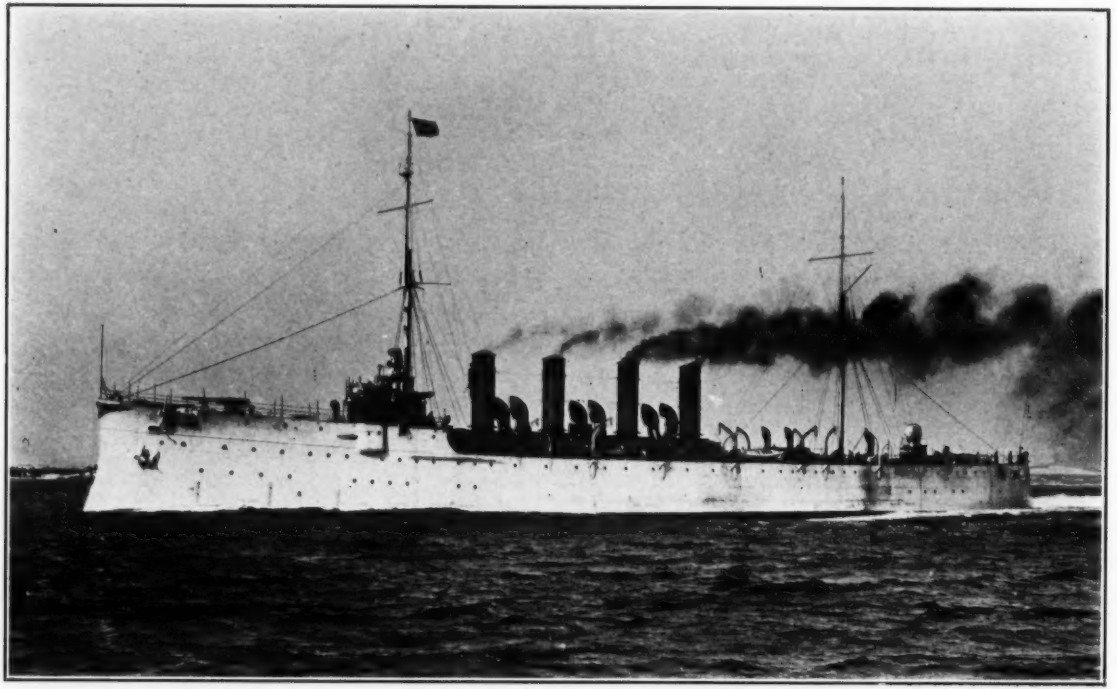
Sulphur has two general effects on coal, and the less there is of it the better will be the general results. The tendency to spontaneous combustion is directly proportional to the sulphur content, and the greater the mass in which coal is to be stored and the longer it is to be kept in storage the less should be the sulphur contained. For coal that is to be stored in large masses for a long time, the best results will be had from "lump coal" instead of "run of mine." Lump coal is naturally the purest and most free from sulphur. It will have considerable ventilation as against none in "run of mine;" it will drain off water readily instead of holding it to produce slow chemical action. The other general effect of sulphur is to form clinker. It is a safe general proposition that the higher the sulphur the higher will be the ash, slate and other inert matter, and under the effects of heat clinkers will form which will kill the draft and more or less injure grate bars and brick linings.

The ash and solid matter shown by analysis will increase in per cent. in actual firing. The smaller the ash shown on analysis the less will be the proportional increase in firing, and the greater the ash on analysis the greater will be the proportional increase in firing. It is claimed that with an ash content of 40 per cent. the evaporative power of coal becomes zero, and this might easily prove to be the case. With low ash the least stoking is required and, consequently, the least opening of furnace doors and cooling effect of excess of air. With high ash much stoking is required, and there results not only the cooling effects of excess of air, but a waste of coal itself from the necessary slicing and overturning of the fire. When high sulphur and high ash produce excessive clinkering, fires must be worked constantly to produce any results at all, and at the best they will be poor.

The calorific value of the steam coals available on the Atlantic Coast will vary between 13,000 and 15,000 British thermal units, and in general be at about 14,000 units, this unit being the amount of heat necessary to increase the temperature of a pound of water by one degree Fahrenheit. The heating value of coal is the first consideration, and varies in general with its analysis. To require the contractor to name the heating value places him "between the devil and the deep sea." The higher he sets it in his bid the more likely is he to get the contract, and if he sets it higher than he can meet he is subject to fines for which he has taken the responsibility in advance. The general result is to produce close competition and a true representation of the coal. The calorific value is determined on dried coal, so that there may be no complications due to varying amounts of moisture at different times.

The calorific value may be set so low that excesses of moisture, sulphur and ash over the specified requirements are possible, and, as these substances affect the practical burning of the coal, a fine is also set for excesses that will keep them within practical bounds.

It is believed that this specification is practical, just and equitable, and will tend to fair competition. If desirable, it may be further modified by asking bidders to set the limits for the substances named where greatly varying coal is likely to be encountered and limited quality is of no great importance.



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U. S. S. "CHESTER."

DESCRIPTION AND TRIALS OF U. S. S. *CHESTER.*

By Lieutenant A. F. H. Yates, U. S. N., Member.

The *Chester* is one of three scout cruisers authorized by an Act of Congress, approved April 24th, 1904. Owing to the rapid development of the steam turbine for marine use, the Navy Department decided to contract for these three vessels to be exactly similar but for their propelling machinery. The contract for the *Chester* was made with the Bath Iron Works, Limited, of Bath, Me., on the 4th of May, 1905, and called for her completion and delivery to the Government on or before the expiration of thirty-six months from the above date. The propelling machinery of the *Chester* consists of Parsons marine steam turbines, driving four independent shafts, each shaft being fitted with one propeller, and cruising turbines fitted to give economy at low power. Exclusive of the cruising turbines there are two main high-pressure turbines exhausting into two low-pressure turbines, and in each of the latter there is incorporated a reversing turbine. To obtain economy at low and moderate speeds the six turbines may be used in three combinations:

First, for low speeds—up to about 18 knots.—The steam passes through all six ahead turbines, both the H.P. cruising and the I.P. cruising being connected up with the four main turbines. Steam admitted to the H.P. cruising exhausts into the I.P. cruising, and from the latter exhausts through separate pipes to each of the main H.P. turbines. From these latter it exhausts into the L.P. turbines and then into the main condensers.

Second, for moderate speeds—up to about 23 knots.—The steam passes through five ahead turbines, steam being admitted

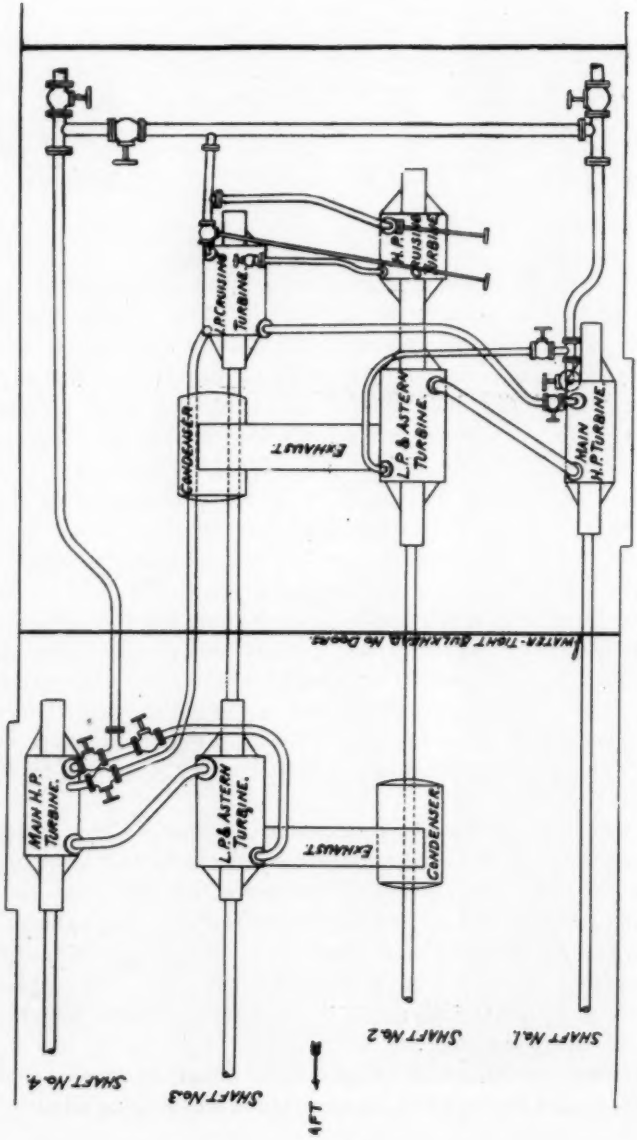

WATER-TIGHT BULKHEAD
H.P. CRUISING TURBINE
L.P. CRUISING TURBINE
CONDENSER
EXHAUST
L.P. & ASTERN TURBINE
MAIN H.P. TURBINE
MAIN H.P. TURBINE
L.P. & ASTERN TURBINE
EXHAUST
CONDENSER
SHAFT No. 4
SHAFT No. 3
SHAFT No. 2
SHAFT No. 1
1 FT

FIGURE 1

to the I.P. cruising turbine and passing thence to the two main high-pressure turbines, and from each of them to the connected low-pressure turbine. The high-pressure cruising turbine revolves idly in a vacuum.

Third, for highest speeds.—Only the four main turbines are used, steam being admitted to each main H.P. turbine. Both cruising turbines revolve idly in a vacuum.

For diagram of arrangement and piping see Figure 1.

Reduction of power in each of the arrangements is obtained by throttling. Increased power may be obtained by admitting live steam to the I.P. cruising turbine in the *first* arrangement and to the main H.P. turbine in the *second* arrangement. By-pass valves are fitted from the first to the second expansions in both main H.P., and auxiliary exhaust steam may be admitted to the second expansions in main H.P. turbines and to both L.P. receiver pipes.

The turbines were designed for a working pressure at the turbines of 250 pounds per square inch and to drive the shafts at 502 revolutions per minute for the contract speed of 24 knots.

The contracts for the other two vessels, the *Birmingham* and the *Salem*, were awarded the Fore River Shipbuilding Company, of Quincy, Mass., the *Birmingham* to be equipped with two vertical, inverted-cylinder, direct-acting, triple-expansion engines of Navy Department's design, and the *Salem* with two seven-stage, Curtis, reversible, marine steam turbines.

General hull data of the *Chester* are as follows:

HULL DATA.

Length between perpendiculars, feet	420
over all, feet and inches	423–02
on water line (16 feet 9.5 inches), feet	420
of straight keel, feet and inches	340–06
Beam, extreme, at 16 feet 9.5 inches W.L., feet and inches	47–01½
on main deck, feet and inches	40–05
Greatest beam, hull proper, situated at normal L.W.L., ft. and ins.	47–01½
Breadth, over all, feet and inches	47–01½
Draught, to top of keel, feet and inches	16–08$^{9}/_{16}$

Molded depth (from top of main-deck beam at side to bottom of frame at M. P.), feet and inches	36–05 5/16
Keel projects below molded base line, inch	00 1/2
Ratio of lengh to beam	8.97
immersed area of longitudinal section to rudder area	34.1
Number of screws	4
Outboard shafts, incline up and forward, angle, degrees	2.46
Inboard shafts, incline up and forward, angle, degrees	1.44
Shafts diverge at an angle with center line of ship, degrees	.72
Outboard shafts, center line at frame No. 78, from center line of ship, feet and inches	10–04
Inboard shafts, center line at frame No. 78, from center line of ship, feet and inches	3–06
Outboard shafts, center line at frame No. 78, from base line, feet and inches	15–10
Inboard shafts, center line at frame No. 78, from base line, feet	12
Outboard shafts, center line at frame No. 131, from center line of ship, feet and inches	12–04
Inboard shafts, center line at frame No. 131, from center line of ship, feet and inches	5–06
Outboard shafts, center line at frame No. 131, from base line, ft.	9
Inboard shafts, center line at frame No. 131, from base line, feet	8
Outboard shafts, rake up and forward per foot, inch	.52
Inboard shafts, rake up and forward per foot, inch	.31
Both shafts, rake outward per foot, inch	.15
Distance of center line of outboard screws forward of A.P., feet and inches	43–02 1/2
Distance of center line of inboard screws forward of A.P., feet and inches	24–07 1/2
Distance of center line of outboard screws from center line of ship, feet and inches	12–04
Distance of center line of inboard screws from center line of ship, feet and inches	5–06 29/32
Strut centers for outboard shaft forward of A.P., feet	46
inboard shaft forward of A.P., feet	28

STEAMING TRIALS.

The wonderful results attained by the *Chester* during her trials far exceeded all expectations and established her as the fastest man-of-war in the world of over 1,500 tons displacement, and, indeed, as the fastest of all the world's large vessels.

The contract required a *progressive* trial over a measured mile course for the purpose of standardizing the screws, extending from maximum speed down to a speed of about 12

knots; a *full-speed* trial of four hours' duration in the open sea, guaranteed speed not to be less than an average of 24 knots per hour as determined by the standardization curve, air pressure not to exceed 5 inches of water, displacement with 475 tons of coal, etc., etc., on board, not to exceed 3,750 tons; two *endurance* and *coal-consumption* trials, each of 24 hours' duration, one to be run at an average uniform speed of about 12 knots under service conditions, and the other to be run at a uniform speed to average not less than 22.5 knots per hour under service conditions, displacement on each trial to average as on *full-speed* trial.

The date set for the beginning of these trials was February 27, 1908, and on February 13th the builders took the *Chester* to the Navy Yard at Charlestown, Mass., for drydocking. There her bottom was cleaned and painted, after which she returned to the works of the company at Bath. After leaving Bath for Charlestown the vessel was taken to Southport, Maine, for a private standardization, but, as the weather was unfavorable, no satisfactory results could be obtained. Both on the run to and from Charlestown the vessel was run at varying speeds to determine the general conditions of the machinery and to become acquainted with existing pressures, etc. On the run to Charlestown it was found that at high pressures on cruising turbines the gland system was not handling all of the gland leak-off steam from the H.P. and I.P. cruising turbines, and consequently an excessive amount of steam vapor found its way into the forward engine room. This was remedied upon arrival at Charlestown by installing a branch pipe from the forward section of gland equalizer piping to the starboard L.P. exhaust to condenser. On starting the port main H.P. turbine on one occasion a slight grinding noise was heard, and upon arrival at Charlestown the casing of this turbine was lifted and the blading examined. The casing blades, particularly in the second expansion, were found to be slightly distorted, and the binding wire broken in a few places. The blades were straightened, filed down somewhat, and soldered. There is no doubt but what this was due to heating the tur-

bine with auxiliary exhaust steam, when warming up before turning the turbine, admission of this steam being at that point, causing local and unequal expansion. This practice was discontinued, and no similar trouble experienced subsequently.

It should, perhaps, be remarked that, previous to the run to Charlestown, a dock trial of the machinery was held at the works. This trial was held on February 6, 1908, and lasted three hours, beginning at 11 A. M. and ending at 2 P. M. From 11 A. M. to meridian steam was admitted to the H.P. cruising turbine, all six turbines being in operation. The average revolutions of all shafts was 197.5. From meridian to 1 P. M. steam was shut off the H.P. cruising turbine and admitted to the I.P. cruising, the former running in a vacuum. Five turbines were then in operation. The average revolutions of all shafts was 191.5. From 1 P. M. to 2 P. M. steam was shut off the I.P. cruising turbine and admitted to both main H.P. turbines. Both cruising turbines then ran idle in a vacuum, the four main turbines being in operation. The average revolutions of all four shafts was 193.4. The machinery worked most satisfactorily throughout the trial. A short backing test concluded the trial. The data obtained, having little significance, is omitted from these papers.

On February 25 the *Chester* left Bath for Rockland, Me., arriving in a few hours. A private standardization trial was held by the builders upon arrival for the purpose of preparing for efficient management of the machinery on the occasion of the official standardization trials. On the 26th instant the Naval Board of Inspection and Survey arrived at Rockland and went on board. The weather being unfavorable upon the date set for the trial (February 27th), the latter was postponed until the next day.

OFFICIAL STANDARDIZATION TRIAL.

The standardization trial was held on February 28th, 1908, beginning at 8·22 A. M. and ending at 12·32 P. M. There were about 325 people on board, comprising Government

representatives, shipyard officials and crew. About 740 tons of coal remained on hand. The vessel carried no other water than reserve feed and was ballasted by handling the coal. The draught and displacement both at beginning and end of the trial was:

	Beginning.	End.
Draught, forward, feet and inches	16–02¾	15–11¼
aft, feet and inches	17–00¾	17–00¼
mean, feet and inches	16–07¾	16–06
Displacement, tons	3,720	3,673
Estimated mean draught at middle of five high-speed runs, feet and inches	16–06¾	
Corresponding displacement, tons	3,696	

The weather was fair, with a light mist at the beginning, gentle breezes from the westward, and a smooth sea with a very light swell from the S.E. Seventeen runs were made over the measured mile, alternately north and south. The first three runs were made at about 12 knots, the next three at about 15.5 knots and the next five at full speed, about 25 knots. Following the high-speed runs three runs were made at about 23 knots and three at about 19 knots.

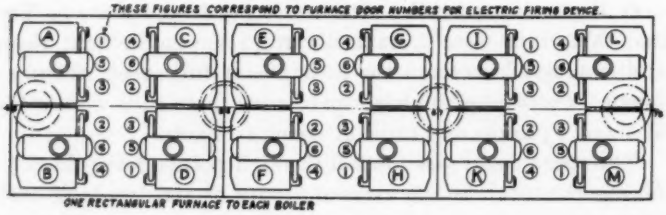
The speed curve was plotted through points determined by taking the mean of the various groups of runs made at each of the five speeds above referred to, and is shown on Fig. 2.

TWENTY-FOUR-HOUR TRIAL AT 12 KNOTS.

At 4·45 P. M. on the same day the *Chester* left the harbor of Rockland for the endurance and coal-consumption trial at 12 knots, the interval between the close of the standardization trial and this time having been utilized for carrying out the anchor test, cleaning the four after boilers, etc. The trial officially began at 5 P. M. The weather was fair and cold, with stiff to fresh breezes from the N.N.W.

On this trial only the after fireroom, boilers I, K, L and M, was used, under natural draft. The following auxiliaries were run: one dynamo, one main feed pump, two main air pumps, two main circulating pumps, two vacuum augmenters, one oil pump, one sanitary pump, steering engine, and

one ash-hoist engine as required. As this run was primarily for the purpose of determining the coal consumption at this speed, coal used was carefully tallied by baskets, though the bunkers were striped, and this latter method relied upon for the exact amount of coal used. The weight of the coal per cubic foot had previously been determined by the Inspector of Machinery, at the works. For this purpose the weight of a bin of coal, containing about 55 cubic feet, was taken. The firing interval on this run was from 1 minute and 30 seconds to 2 minutes, and was based on supplying three shovels, or about 40 pounds, each time. The furnace doors were numbered as shown in the figure. As will be seen, the numbers are so arranged that no two adjacent doors have the same number.



The Corey time-firing device installed displays in succession the numbers 1, 2, 3, 4, 5, 6, at such intervals as desired. It consists of a cylindrical case with a glazed opening near the bottom, back of which there is fixed a fixed white incandescent light. Between the light and the glazed opening there is a revolving aluminum dial, actuated by an electromagnet with stenciled figures from 1 to 6 inclusive. A motor-driven transmitter is located in the forward engine room and so wired to indicators that the numbers will be indicated in all firerooms at the same time. Upon the display of a number the furnace doors bearing that number were opened and the fires therein coaled or raked, the latter being left to the judgment of the fireman. This general practice was followed throughout the succeeding trials.

During this run the eight boilers in No. 1 and No. 2 fire-rooms were cleaned preparatory to the *full-speed* trial.

All six turbines were in use, steam being admitted to the H.P. cruising turbine. All machinery worked most satisfactorily throughout the entire run. The average revolutions per minute were 249.69, corresponding speed 12.2 knots. The total coal burned was 43.832 tons, 6.68 knots per ton of coal.

Draught and displacement :

	Beginning.	End.
Draught forward, feet and inches	16–05$\frac{7}{8}$	16–02$\frac{5}{8}$
aft, feet and inches	16–11$\frac{3}{8}$	16–09$\frac{5}{8}$
mean, feet and inches	16–08$\frac{3}{4}$	16–06$\frac{1}{8}$
Displacement, tons	3,750	3,671
Estimated mean draught at middle of trial, feet and inches	16–07$\frac{7}{16}$	
Corresponding displacement, tons	3,710	

FOUR-HOUR FULL-POWER TRIAL.

At the conclusion of the last trial, at 5 P. M., February 29, it was necessary to enter port, clean fires and prepare for the *full-speed* trial. The ship proceeded to Portland, Me., and anchored at 5·45 P. M. The four after boilers were cleaned, a load of fresh water taken from a tug boat and the ship ballasted with salt water.

Steam was raised on all twelve boilers.

At 1·30 A. M., on the morning of March 1, the *Chester* left port and at 2·5 A. M. the full-power trial officially began. Bagged coal was used entirely on this run. The four main turbines were used, the cruising turbines running idle in a vacuum. The entire installation worked to perfection. No trouble was experienced with auxiliaries except that the main feed pumps were taxed beyond their capacity and the auxiliary feed pumps had to be used. The auxiliary feed pump in No. 1 fireroom was in use most of the time, that in No. 2 fireroom was run slow a greater part of the time and that in No. 3 fireroom kept in reserve.

The weather was clear and cold with moderate W.N.W.'ly breezes and the sea smooth.

The boilers supplied steam without effort; safety valves were set at about 262 pounds, and steam necessary to main-

tain about 240 pounds at the turbines was kept from beginning to end. The firing interval used was 20 seconds.

The following statement shows the draught and displacement on leaving port and at end of trial:

	Beginning.	End.
Draught, forward, feet and inches	16-04¼	15-07⅝
aft, feet and inches	16-10⅛	16-09
mean, feet and inches	16-07⅛	16-02$\frac{5}{16}$
Displacement, tons	3,731	3,583
Estimated mean draught at middle of run (8 inches by the stern), feet and inches	16-06	
Corresponding displacement, tons	3,673	

TWENTY-FOUR-HOUR TRIAL AT 22.5 KNOTS.

Upon the conclusion of the full-power trial at 6·05 A. M., March 1st, the *Chester* proceeded to Portland, Me., for water and for the purpose of cleaning boilers and otherwise preparing for the *endurance* and *coal-consumption* run at 22.5 knots. Owing to bad weather departure was delayed until 10·14 A. M., March 3d. The draught and displacement on leaving and at end of run was as follows:

	Beginning.	End.
Draught, forward, feet and inches	16-11$\frac{1}{16}$	15-09⅝
aft, feet and inches	16-10$\frac{9}{16}$	16-08½
mean, feet and inches	16-11¼	16-02⅞
Displacement, tons	3,835	3,596
Estimated draught at middle of run, feet and inches	16-07¼	
Corresponding displacement, tons	3,716	

The contract contained a penalty clause in connection with this trial, as follows: "If the average speed of 22.5 knots cannot be maintained for the twenty-four hours' endurance and coal-consumption trial, it shall be optional with the Secretary of the Navy to reject her, or to accept her at a reduced price and upon conditions to be agreed upon; provided, that if the coal consumed for all purposes on the twenty-four hours' endurance and coal-consumption trial give an endurance of less than 1.8 knots per ton of coal burned at the speed of 22.5 knots, or less than 1.6 knots per ton of coal burned at a speed of 23.5 knots, or less than a proportionate endurance

per ton of coal burned at other speeds above 22.5 knots, deductions shall be made from the contract price at the rate of $15,000 in each case for every .1 knot of endurance per ton of coal below the endurance required above."

At 10·44 A. M., March 3d, the trial officially began. The weather was overcast and cloudy, with light airs to stiff breezes from N.N.E. to W.N.W., and a smooth sea. The following auxiliaries were in use: Auxiliaries in connection with the operation of the main engines, including two main feed pumps, two dynamos, all hull-ventilating fans, evaporating and distilling plant, flushing pump, forced-draft fans, steering engine, steam heaters, one ice machine at 75 revolutions per minute, and the fresh-water pump as required. All twelve boilers were used under light air pressure. All steam from boilers was admitted to the I.P. cruising turbine; the high-pressure cruising turbine ran idly in a vacuum. Turbines, boilers and auxiliaries, all worked most satisfactorily. Bagged coal entirely was used for the first seven hours. Loose bunker coal used was kept track of as on 12-knot run. The firing interval was one minute.

The trial concluded at 10·44 A. M., March 4th, and was followed by backing, helm, and steering-engine tests. These tests were also held at the conclusion of the *full-speed* trial, but were at this time repeated. With the vessel running at full speed ahead, about 24 knots, the telegraphs were thrown to "full speed astern," and the vessel became dead in the water in 2 minutes and 37 seconds. While running at full speed astern, about 350 revolutions per minute, the telegraphs were thrown to "full speed ahead," and the vessel became dead in the water in about one minute.

With the helm hard over, at full speed ahead, a turning circle, estimated at 700 yards, was completed in 5 minutes and 27 seconds, the initial angle of heel being 30.7 degrees and the permanent angle 1.8 degrees.

While backing full speed the highest steam pressure at astern throttle was 146 pounds, giving about 400 revolutions;

120 pounds gave about 350 revolutions. With the inboard shafts backing at 400 revolutions the outboard shafts ran idle at nearly 200, and with the inboard shafts backing at 350 the outboard ran idle at about 150.

The average revolutions per minute were 473.343, corresponding speed 22.782 knots. The total coal burned was 193.54 tons, 2.82 knots per ton of coal.

STANDARDIZATION TRIAL DATA.

No. and direction of run.	Interval between middle of runs.		Average of elapsed times observed.		Mean revolutions per min.	Speed in knots.
	Min.	*Sec.*	*Min.*	*Sec.*		
1 N.	...	...	5	18.75	251.88	11.2941
2 S.	17	06.3	4	33.35	242.88	13.1700
3 N.	20	02.5	5	18.45	251.07	11.3048
4 S.	about 19	...	3	38.85	317.04	16.4496
5 N.	16	20.1	4	08.90	319.97	14.4637
6 S.	15	51.5	3	33.90	319.65	16.8303
7 N.	about 13	...	2	30.95	545.06	23.8492
8 S.	12	05.7	2	17.75	542.43	26.1347
9 N.	12	11.1	2	29.65	546.69	24.0558
10 S.	12	46.8	2	17.30	545.83	26.2203
11 N.	13	21.7	2	30.50	545.87	23.9206
12 S.	about 17	...	2	28.00	482.68	24.3240
13 N.	15	18.4	2	42.80	486.51	22.1133
14 S.	14	54.5	2	27.70	484.31	24.3734
15 N.	...	...	3	16.05	402.31	18.3627
16 S.	17	04.7	2	35.55	400.24	20.5304
17 N.	16	34.9	3	15.10	400.75	18.4519

The vessel proceeded to Portland, Me., where the Board of Inspection and Survey disembarked, after which she returned to the works of the builders, Bath, Me. The usual custom was observed of painting on the smoke stacks the speed made at full power, and lashing brooms at the masthead and yardarms. The greater part of the Bath population met the vessel at the dock and a salute was rendered by them of 26 guns, one for each knot made, with a historic cannon belonging to the city.

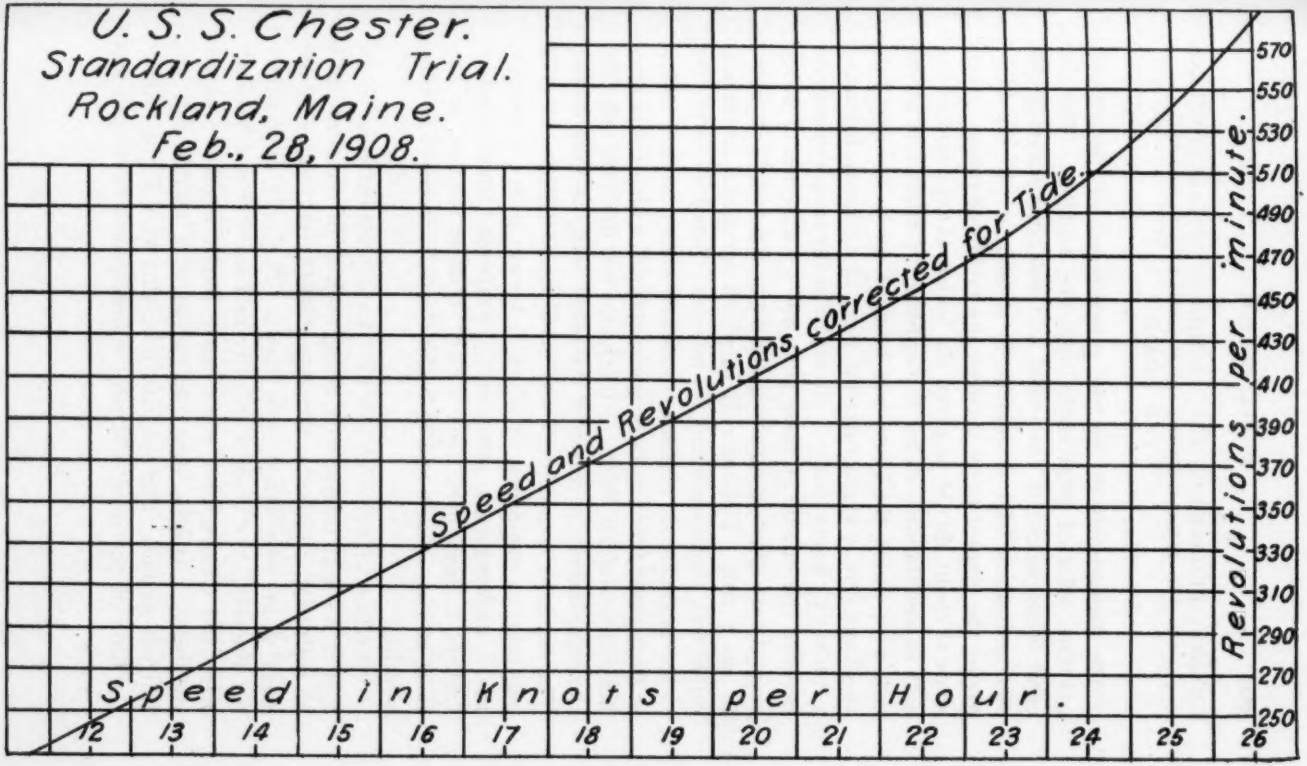

U. S. S. Chester.
Standardization Trial.
Rockland, Maine.
Feb., 28, 1908.
Speed and Revolutions corrected for Tide.
Speed in Knots per Hour.
Revolutions per minute.
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
250
270
290
310
330
350
370
390
410
430
450
470
490
510
530
550
570

Plate II.

GENERAL REMARKS ON THE MACHINERY INSTALLATION AND ON ITS MANAGEMENT AND OPERATION DURING THE TRIALS.

The management of the trial program and of the individual trials reflected great credit upon the builders. The efficient management of the vessel and machinery during the standardization trial is evident by a reference to the table giving the elapsed times between the middle of runs. A full share of credit should be given the boilers as exhibited by the ease in maintaining steam throughout the trials and by the ease with which the vessel was brought up to her first full-speed run (No. 7 standardization run), of 25 knots, following a run at 15.5 knots (No. 6). As noted in the table the interval between the middle of these runs was 13 minutes, of which several were spent in finishing No. 6 run and several included in No. 7 run. The interval in which increased steam was raised was, therefore, about six minutes. Attention is invited to the moderate air pressures carried, as shown on data tables. A high-grade fireroom force was employed, which could have been improved on little. No attempt was made at reducing the complement by reason of the vessel being turbine driven. The engineer complement was made up as follows: 1 chief engineer, 21 engineers, 18 oilers, 6 blower oilers, 6 machinists, 6 messengers, 4 pump men, 3 evaporator men, 2 boilermakers, 1 steam-heat man, 1 clerk, 9 water tenders, 49 firemen, 28 coal passers and 12 boiler cleaners, arranged in three watches.

Vibration of turbines and hull were practically *nil* at all speeds, a slight tremor only being noticed in the after cabin at top speed, a propeller influence. Both the bow wave and stern wake were remarkably small. The only opportunity for observing the vessel's stability in a sea way was between Bath and Charlestown, when fairly rough weather was encountered. At this time the period of a double roll was thirteen seconds. The machinery weights were slightly under the limit of 798 tons, whereas the horsepower developed was

much greater than the designed 16,000. The machinery compartments were never uncomfortably warm, though it must be remembered that the weather was cold and the ventilation especially efficient. The oil service worked most satisfactorily and bearing temperatures were in no case excessive. The coal used on the trial was Pocahontas, and samples of the lots used on the various trials were tested with the following results:

Selected Pocahontas coal.	4-hour test.	24 hours at 12 knots.	24 hours at 22.5 knots.
	Per cent.	*Per cent.*	*Per cent.*
Moisture	1.18	1.18	1.16
Volatile matter	19.50	20.14	20.21
Fixed carbon	75.78	75.54	76.03
Ash	3.54	3.14	2.60
Total	100.00	100.00	100.00
Sulphur	0.61	0.60	0.61
Heat value in B.T.U.	14,740	14,830	14,896

Arrangements were made by the contractors for obtaining water-consumption data by a system of measuring the feed-pump volumes, but as the data obtained was not considered reliable it is omitted from these papers.

POST-TRIAL EXAMINATION OF BOILERS AND MACHINERY.

Instructions were given the builders by the Trial Board upon the conclusion of the trials to have the boilers opened for complete inspection, all turbine covers lifted, and other features of the installation prepared for post-trial examination in accordance with current practice. A report was made by the builders on the 7th of March that they would be ready on the 9th instant. The Trial Board arrived at Bath on that date. The examination showed the boilers to be in fine condition, a small amount of brickwork having been re-made, and the turbines and auxiliaries in excellent shape. Indications of blades having rubbed (in spots) were noticed in the

four main turbines, but this was not sufficient to warrant anxiety or to necessitate other than slight reduction in tip clearances here and there. The journal-bearing bridge-gauge clearances taken after trial were:

BRIDGE-GAUGE MEASUREMENTS ON JOURNAL BEARINGS.

H.P. C., forward bearing	.018
after bearing	.027
I.P. C., forward bearing	.032
after bearing	.012
Starboard H.P., forward bearing	.038
after bearing	.010
Starboard L.P., forward bearing	.022
after bearing	.021
Port H.P., forward bearing	.023
after bearing	.008
Port L.P., forward bearing	.019
after bearing	.002

Following the trials and this examination, work in connection with the final completion of the vessel for delivery to the Government was begun. This consisted principally in laying linoleum, cleaning, painting, lagging, etc., and making good what few minor defects were noted, such as leaky valves, joints, etc. Journal bridge-gauge clearances were taken, other such data collected, and stores assembled. The vessel was finished on April 23, 1908, and, ten days before the expiration of the contract time, on April 24th, she was taken to the Navy Yard, Portsmouth, N. H., and there delivered to Rear Admiral Bicknell, U. S. N., the Commandant of the yard.

The vessel was secured at the dock at noon, and at 2 P. M. the Board of Inspection inspected the vessel, finishing at 3·45 P. M. Promptly upon the conclusion of the inspection the ship was taken over and the engineer department relieved by a tentative organization. The ship was placed in commission at 10 A. M. April 25th.

DESCRIPTION OF PROPELLING MACHINERY.

The propelling turbines are in general as set forth at the beginning of the article, six in number, an H.P. cruising, I.P. cruising, two main high pressure and two low pressure, with reversing turbines incorporated into the exhaust ends of each of the latter. The reversing turbines revolve idly in the exhaust casing of the L.P. turbine when the engines are running ahead. Arrangement has been referred to in Figure No. 1. As shown therein, they are located in two compartments separated by an athwartship, watertight bulkhead. The inboard shafts turn outboard and the outboard shafts turn inboard.

The turbine cylinders are parted horizontally in the plane of the shaft, and the two halves strongly bolted together. The lower half is cast with extensions forward and aft, box shaped, for retaining the journal and thrust bearings. The cylinders are supported by feet, certain of which are securely bolted to the foundations and others have slotted holes for expansion. The feet are at a point directly under the journal bearings. The cylinders contain supports for the spindle and thrust-bearing brasses with oil pockets, also the lower halves of spindle glands, and have pockets under these glands for steam leak-offs. They have internal facings at their ahead steam ends for bolting on the dummies. Cylinder blading is calked into grooves on the inside of the cylinder castings, these portions of the cylinders having been accurately bored and finished in a horizontal position. Hydrostatic tests were first applied to the cylinders, and subsequently a "baking" under moderate steam pressure for 48 hours to relieve internal stresses in the castings. The following table shows arrangement and dimensions of blading.

The rotors were statically balanced on two truly-leveled rails and the balance adjusted by removing metal, as necessary, from "chipping strips" left on the arms of the rotors for the purpose. The dynamic balancing was done by revolving the rotors under steam. At the same time dummy ring faces were worn down, and bearings adjusted.

Stages.	Expansions.	Rows.	Heights, Inches.	Pitch, Inches	Clearances, Inches.
		H.P. Cruising.			
1st	1st	12	$\frac{5}{8}$	$\frac{7}{8}$	.03
2d	2d	12	$\frac{1}{2}$	$\frac{7}{8}$	.035
3d	3d	12	$\frac{3}{8}$	1	.04
		I.P. Cruising.			
1st	1st	15	$1\frac{1}{8}$	$1\frac{1}{4}$	.04
2d	2d	15	$1\frac{7}{16}$	$1\frac{1}{4}$	.04
3d	3d	15	$1\frac{3}{4}$	$1\frac{5}{16}$	.045
		Main High Pressure.			
1st	1st	12	$\frac{7}{8}$	$1\frac{1}{4}$	.03
2d	2d	12	$1\frac{1}{4}$	$1\frac{1}{4}$	.035
3d	3d	12	$1\frac{3}{4}$	$1\frac{5}{16}$	.04
4th	4th	12	$2\frac{1}{4}$	$1\frac{3}{8}$	.045
5th	5th	12	$3\frac{1}{4}$	$1\frac{7}{16}$	.05
6th	6th	10	5	$1\frac{1}{16}$	.05
		Main Low Pressure.			
1st	1st	5	$2\frac{1}{4}$	$1\frac{5}{16}$	.055
2d	2d	5	$3\frac{1}{4}$	$1\frac{3}{8}$	.06
3d	3d	4	5	$1\frac{1}{16}$	.07
4th	4th	3	7	$1\frac{1}{4}$	.08
4th	5th	3	7	$1\frac{1}{16}$	.08
4th	6th	4	7	$2\frac{5}{16}$	.08
4th	7th	4	7	$2\frac{5}{12}$	.08
		Astern Turbines.			
1st	1st	6	$\frac{1}{2}$	$1\frac{1}{4}$	.045
2d	2d	6	1	$1\frac{3}{8}$	.05
3d	3d	6	2	$1\frac{3}{8}$	.06
3d	4th	6	2	$1\frac{1}{2}$	.06
3d	5th	6	2	$1\frac{1}{2}$	.06

The blades were installed in accordance with the Parsons system. They were cut to length, saw-cuts made where required for binding, calking grooves stamped into the base of the blades, all done by the same machine, and the blades then calked into place. Calking strips having curves corresponding to the blades were cut to length and placed alternately at the base of each blade. The blades and calking strips were

alternately tightened into the groove by means of a calking tool, after which the binding wire was inserted and the lacing put on around binding wire and blades with silver solder. Blades were turned up in the vertical line before the insertion of the binding wire, and were finally filed up to remove burrs.

The blades are of a composition consisting of 72 per cent. copper and 28 per cent. zinc, the calking strips 63½ per cent. copper and 36½ per cent. zinc, the binding strip 72 per cent. copper and 28 per cent. zinc, and the lacing wire pure copper. Blades having binding strips are soldered to the latter with a silver solder. Steam supply and exhaust piping is as shown on Fig. 1. In the exhaust pipe from H.P. cruising turbine to I.P. cruising turbine, and in the two exhaust pipes from the I.P. cruising to the main H.P. turbines, spring-loaded, self-closing valves are installed to isolate the cruising turbines while running at higher rates of speed and while maneuvering. A 3½-inch spring-relief valve for the H.P. cruising turbine is installed in its exhaust pipe, set at 125 pounds, and one for the I.P. cruising turbine is installed on after end of its upper casing, set at 160 pounds. A governor, arranged to pull out a pawl and close a butterfly valve in the main steam pipe, is fitted on each shaft, the object being merely to shut down automatically in the event of accident. An unusual feature in piping is the low-pressure exhaust pipe, which is an elbow pipe rectangular in cross section, 3 feet 9 inches by 4 feet 6 inches and of ⅜-inch steel plate. The dummies in the steam ends of turbines for preventing steam from leaking from steam belts direct to the inside of drums consist of a series of rectangular grooves in the spindle wheels against the side of each of which a brass strip lies closely without touching. These brass strips are calked into an annular iron casting made in halves and bolted to the inside of the cylinder. A micrometer for measuring the opening of dummies between brass strips and running steel faces is fitted on each cylinder. Steam glands are fitted around turbine spindles at cylinder ends, packed with labyrinth stuffing boxes. These glands are to obviate, in the case of high-pres-

sure turbines, the leakage of steam from the casings, and in the case of the low-pressure turbines, the leakage of air from the atmosphere into the casing and thence to the condenser. There are rows of brass strips let into the shaft and the cast-iron gland sleeve, with thin edges just clearing the opposite member. Snap rings of composition H are fitted at the outer end of each gland box, and just inside of these rings connection is made with an equalizer pipe joining all similar pockets, and a valve is provided from auxiliary exhaust line for maintaining the pressure in this pipe. Strainers of the basket type in accordance with current turbine practice, made with bodies and covers of composition G, and with strainer baskets of sheet brass, are installed, one in the live-steam supply to each turbine and one in the auxiliary exhaust connection to the second expansion of the main H.P. turbines and L.P. turbines. A system of guide rods is installed for lifting turbine casings, one on each of the four corners, placed vertically and graduated in inches, to permit of the even lifting of the covers. Special portable guides are supplied for guiding the spindles when lifting them, to prevent the stripping of blades. Turning gear is fitted at the after end of each turbine for turning it by hand. It consists of a wormwheel on the shaft, meshing with a worm operated by a ratchet wrench. Suitable lifting gear is provided for lifting casings, spindles, etc., consisting of overhead trolleys on frames, with chain falls and slings. Turbine cylinder data follows:

Cylinder.	Diam. of rotor drum, inches.	Length of rotor drum, inches.	Diameter of cylinder for each stage. 1st inches.	2d inches.	3d inches.	4th inches.	5th inches.	6th inches.	7th ins.
H.P. cruising	60	36	60¾	61	61¼	...	...	...	...
I.P. cruising	49	60.5	51¼	51⅞	52.5	...	...	...	...
Main H.P. port	42	103.5	43¾	44.5	45.5	47	49	52	...
starboard.	42	103.5	43¾	44.5	45.5	47	49	52	...
L.P. port	65	53⅜	70	72	75	79	79	79	79
starboard.	65	53⅜	70	72	75	79	79	79	79
Astern, port.....	50	43	51	52	54	54	54	...	...
starboard.....	50	43	51	52	54	54	54	...	...

SHAFTING AND SHAFT BEARINGS.

The shafting is of Class "A" forgings and is solid. The thrust shaft is on spindle ends. The stern-tube shaft and propeller shaft is in one piece, inboard sections 48 feet 3 inches long and outboard lengths 46 feet 9$\frac{1}{2}$ inches long, in both cases 8$\frac{1}{2}$ inches diameter. The line shafting is 8 inches in diameter. There are two shaft bearings to each turbine—twelve in all—those for the cruising turbines being 10 inches long and those for the main turbines 15 inches. The bearing shells, of brass, are semi-circular and are lined with white metal. Broad strips of the bearing shell are exposed slightly below the line of the white metal to catch the spindle in case the white metal gives out. The bottom half can be rolled out without lifting the spindle, the top half will lift off. These bearings are lubricated by oil supplied under pressure. There are six thrust-shaft bearings, those for the cruising turbines having eight collars and rings, those for main turbines fifteen collars and rings. These bearings are so constructed that the longitudinal position of the shaft and the dummy clearance can be readily adjusted. The thrust bearings are in two halves. The steam balance is so arranged as to be practically equal to the thrust of the propeller at all speeds. The thrusts are lubricated by oil under pressure. Oil supplied to thrust bearings and journal bearings is collected in a chamber in the box ends of lower cylinder castings, and drains by gravity into a return pipe. There are fifteen line-shaft bearings each 12 inches long, lined with white metal, and with ends provided with oil baffles; provision is made for their lubrication by oil under pressure. Water service to a jacket around oil chambers is provided only in case of line-shaft bearings, the water-service pipe discharges into stern-tube stuffing box and has a branch pipe for draining the latter. Water service by hose can be provided in emergency. Stern-tube bearings for each shaft consist of a bearing in each end of the tube in each case. They are each 51$\frac{3}{4}$ inches in length. Each shaft also has one strut bearing, 51$\frac{3}{4}$ inches in length, and fair-water sleeves are fitted on the forward side of the strut at one end,

and on the after side of the stern tube at the other. There are sixteen bulkhead stuffing boxes where shafts pass through watertight bulkheads.

An expansion coupling is fitted between each L.P. turbine and the cruising turbine on same shafting. The forward end of each L.P. turbine shaft is built with 12 teeth which engage with a slotted collar bolted to the flange coupling on after end of cruising-turbine shafting. This permits of disconnecting cruising turbines, as well as of expansion. As but slight increase efficiency is gained by disconnecting, this is not done as a rule, the cruising turbines being run idle in a vacuum when not in use.

PROPELLERS.

There are four solid, true-screw, manganese-bronze propellers, each having three blades; diameter, 6 feet; pitch, 6 feet; area, projected, 17.02 square feet; helicoidal, 19 square feet; disk area, 28.27 square feet; immersion of upper tip of blade, 69½ inches, inboard, 57½ inches, outboard. The driving surfaces of all propeller blades were made a true surface by machining. The wing propellers are ahead of the inner propellers, and the former turn inboard and the latter outboard, though it was originally intended that all four turn outward.

MAIN CONDENSERS.

There are two main condensers, one in each engine room, located inboard and abreast of each L.P. turbine. They are horizontal and cylindrical, of the surface-condensing type. The shells are made of Class "B" boiler plate, water chests of composition, tubes of composition and tube sheets and supporting plates of "rolled naval bronze." The forward water chest, being the one for the entrance and exit of circulating water, has a division plate with a 7-inch by-pass valve on outside of chest. Each water chest has eight 10-inch manholes fitted with composition covers, inside of which are placed zinc plates. The following is the data for each:

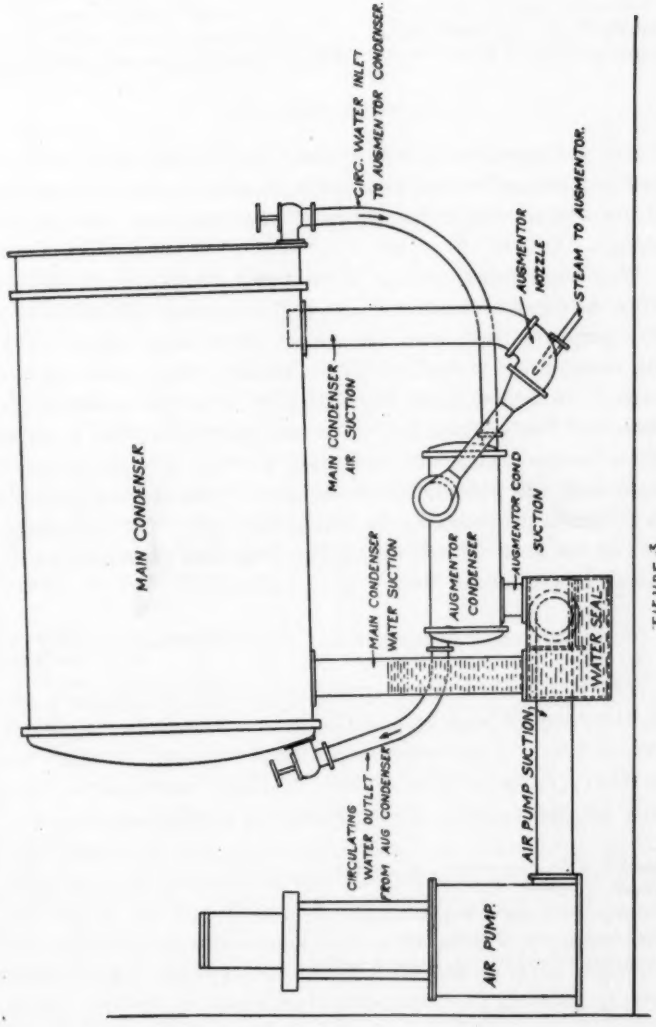

CIRC. WATER INLET TO AUGMENTOR CONDENSER.
AUGMENTOR NOZZLE
STEAM TO AUGMENTOR.
MAIN CONDENSER AIR SUCTION
MAIN CONDENSER
AUGMENTOR COND SUCTION
MAIN CONDENSER WATER SUCTION
AUGMENTOR CONDENSER
WATER SEAL
AIR PUMP SUCTION
CIRCULATING WATER OUTLET FROM AUG CONDENSER
AIR PUMP

FIGURE 3

Cooling or heating surface, square feet	8,999
Number of tubes	5,630
Thickness of tubes B.W.G.	18
Outside diameter of tubes, inch	$\frac{5}{8}$
Length of tubes as fitted, feet and inches	10–0$\frac{1}{4}$

AUGMENTER CONDENSER.

An arrangement called a "vacuum augmenter," devised by the Parsons Turbine Company, is installed for the purpose of increasing the vacuum above that obtained by the air pump.

The augmenter consists of a steam syphon drawing air from the condenser and discharging it to the air-pump suction at a pressure from 1 to 1$\frac{3}{10}$ inches of mercury higher than the condenser pressure. The discharge from the syphon passes through a small condenser in order to condense the steam of the syphon jet. The air pump also has a direct water suction from the condenser through a pipe having a water seal and holding a head of water equal to the difference in pressure produced by the augmenter jet. The augmenter was in use at all times during the trials and produced an increase in vacuum of from 1 to 1$\frac{1}{4}$ inches.

AUXILIARY CONDENSER AND DYNAMO CONDENSER.

There is one auxiliary condenser located on the port side of the forward engine room. It is horizontal, cylindrical, and of the surface-condensing type, connected, through the auxiliary exhaust pipe, to all auxiliary machinery. It is only for use in port. Its dimensions are as follows:

Cooling or heating surface, square feet	601
Number of tubes	630
Thickness of tubes B.W.G.	18
Outside diameter of tubes, inch	$\frac{5}{8}$
Length of tubes as fitted, feet and inches	6–0$\frac{9}{16}$

A similar condenser is located in the dynamo room for the exclusive use of the dynamo engine. Its dimensions follow:

Cooling or heating surface, square feet	202
Number of tubes	212
Thickness of tubes B.W.G	18
Outside diameter of tubes, inch	$\frac{5}{8}$
Length of tubes as fitted, feet and inches	6–$\frac{9}{16}$

FEED HEATERS.

A vertical, dead-end, cylindrical feed-water heater is located at the forward end of each engine room on the discharge side of the main feed pumps. The heating agency is steam from the auxiliary exhaust line, which enters the shell at the top, circulates around the tubes over a system of baffles, and drains at the bottom through a trap to the condenser. An air coil is fitted in the lower water chest, with one end extending into the heater to a point where air forms between the water and the steam. This coil leads direct to the condenser. A drain at the bottom of the heater conducts the condensed water to a trap, thence to the condenser. The feed water passes through the tubes. The tubes contain twisted brass strips held in place by a perforated plate over the tube sheet to retard its flow and insure efficient heating. The dimensions of the heater are as follows:

Heating surface, square feet	601
Number of tubes	630
Thickness of tubes B.W.G	16
Outside diameter of tubes, inch	$\frac{5}{8}$
Length of tubes as fitted, feet and inches	6–$\frac{5}{16}$

FEED AND FILTER TANKS.

There are located in the after part of each engine room combined feed and filter tanks, each of about 1,500 gallons capacity. A partition divides each tank into two parts, one part being for the filter and the other for feed tank proper. The capacity of the former is about 300 gallons and of the latter about 1,200 gallons. The filter has an inner bottom of bolted perforated plates, and is divided by a series of vertical partitions. The partition plates are in pairs, one secured to the top and the other to the bottom of the filter; the passage

of water from one chamber to the next being under the hanging partition plate, up between the two and over the top of the standing partition. The entering water flows into the first chamber over the top of a plate and leaves the last chamber in like manner, these plates forming, with the sides of the tank, entrance and exit chambers, insuring that the filter chambers are always filled and the filtering material submerged.

STEERING GEAR.

The vessel is fitted with a Hyde Windlass Company's steam-steering engine, the operating valve of which is controlled by a telemotor located in the pilot house. This telemotor is connected up with a line of piping to another telemotor located on the steering engine in the steering-engine compartment aft, from which this controls the operating valve. The operating valve of the engine also closes automatically when the rudder has moved to a position corresponding with the number of turns given the steering wheel. The power is transmitted to the rudder head by the customary right and left-handed screw shaft. The vessel can be steered by steam as follows, viz: (a) the bridge; (b) the pilot house; (c) the steam-steering engine itself; and (d) by hand from the steering-engine room.

Also a direct hand steering is provided for an emergency by an arrangement of relieving tackles, direct-connected to the crosshead on rudder head. The power is transmitted to the rudder head by having a tackle passed around a drum, the drum being connected by a spur-wheel, gear and pinion through a worm and wheel to the hand-steering wheels. A clutch is provided on the worm shaft for disconnecting the emergency gear from the hand-steering wheels. There is fitted over the screw shaft a positive helm-angle indicator, and before connecting up for steering from any given position this indicator and all other indicators should be in the central position, or in same relative position to each other. There is further fitted a friction brake on the rudder head

operated by a hand wheel just forward of bulkhead No. 131, which brake is of sufficient power to lock or hold the rudder while shifting steering positions or making repairs. On the forward bulkhead in the steering-gear room is an oil tank for oiling the gear, which should never be allowed to become empty. From it pipes are led to the bearings and crosshead. Except when in actual use cocks in the piping should be kept closed. The hand-steering wheels are always disconnected when steering by steam.

DATA.

Number of cylinders in engine	2
Diameter of cylinders in engine, inches	12
Stroke, inches	10
Steam working pressure, pounds	150
Total area of rudder, square feet	195
Area of balanced portion, square feet	33
Radius of crosshead, inches	28
Angle of rudder between steering-engine stops from hard-a-starboard to hard-a-port, degrees	70
Angle between stops on stern post, degrees	76
Diameter of turning circle with rudder hard over, yards	about 500

ANCHOR WINDLASS.

The windlass is of the worm-gear type, with vertical wildcat shaft and gypsy heads, built by the Hyde Windlass Company. The engine is an inverted, vertical, compound engine, with H.P.-cylinder diameter 10 inches, L.P. cylinder 12 inches, and a stroke of 10 inches.

EVAPORATING AND DISTILLING PLANT.

This plant is made up of four evaporators and four distillers, the former being located in an evaporator room over forward end of forward engine room. The evaporators have a combined capacity of 16,000 gallons of water per day and the distillers a combined capacity of 16,000 gallons of potable water per day. The distillers are located in a trunk leading up from the evaporator room. The evaporators are of the

usual navy type, built by the Bath Iron Works, and each has 223.7 square feet of tube-heating surface; the tubes are 2 inches outside diameter No. 12 B.W.G. and number 84 for each evaporator. The distillers have 80.5 square feet of cooling surface each, tubes are $\frac{5}{8}$-inch outside diameter, No. 16 B.W.G., and straight; number for each distiller, 127. The steel flanges on the shell of the distillers are made in the form of a diaphragm to take up the shell expansion, obviating the necessity for a stuffing box.

REFRIGERATING PLANT.

The refrigerating plant is located on the orlop deck slightly forward of the machinery space. Two vertical, one-ton, Allen dense-air ice machines are installed, one on either side of the compartment, with connections to cold-storage rooms, scuttle butt and ice-making box. The refrigerator is made up of an officers' cold-storage room to starboard and a crew's cold-storage room to port, with an entry between, the latter opening into the ice-machine room, and inside to both of the storage compartments. A manifold regulates the combinations in which the different circuits may be run.

HEATING PLANT.

Radiators are installed in the various parts of the ship for steam heat. The system is divided into eight circuits, in two groups. The forward group comprises the heaters for the chart house and emergency cabin, general pantry and sick bay, crew's quarters, galley and bath heaters. A valve system for regulating the latter is located in the forward uptake, port side. The after group comprises the heaters for the pantries and bath heaters aft, captain's quarters, wardroom officers' quarters, warrant officers' quarters and steering-engine room. The valves for regulating the after group are located over the feed tank in the after engine room. Provision is made for heating water in all lavatories and bath rooms with steam.

ASH HOISTS.

One ventilator in each boiler compartment is fitted for the necessary gear for hoisting ashes to the main deck. One ash-hoist engine of Hyde Windlass Company type is fitted in each case, and is of sufficient power to hoist 300 pounds from the fireroom floor to the upper deck in 5 seconds under steam at 150 pounds pressure. Each engine has two cylinders with cranks at right angles with follow-up gear. Data as follows: 4½-inch stroke, 4½-inch cylinder diameter.

There is also installed in each fireroom on the port side outboard an ash ejector of the See type. These ejectors are connected to the fire and bilge pumps, and discharge five feet above the water line. The hoppers are proportioned to discharge at least 4 cubic feet of ashes per minute.

FORCED-DRAFT BLOWER SYSTEM.

The closed-fireroom system is fitted, two 5×5 double upright blower engines of B. I. W. design being installed for each boiler compartment, making a total of six. They are located near the center line of the ship over their respective compartments on the orlop deck. Their dimensions are as follows: Diameter of steam cylinder, 5 inches; diameter of piston rod, 1⅛ inches; stroke, 5 inches. The blowers are arranged in pairs, with a connecting shaft between the two fans, so that both fans run at the same speed and, in case of accident to one engine, both fans may be run with the remaining engine. The fans are 84 inches in diameter, with nine vanes, and discharge from the periphery ends of vanes.

LUBRICATION.

The lubrication of all main-journal bearings, thrust bearings and line-shaft bearings is by oil supplied under about 10 pounds pressure by steam-driven oil pumps. The oil passes through a cooler on its way to the bearings. Tanks of 150 gallons capacity are located in the lower parts of engine rooms, one in each, from which the oil pumps draw. These

tanks take the return of the oil from all bearings supplied with forced lubrication, by gravity. The discharge of the oil from turbine bearings is through glasses so that the flow can be observed, and thermometers are fitted to these discharges. The oil pipes are all of copper and have no valves fitted either to or from the bearings. Two pumps, Blake, vertical, simplex-piston type, 10×9×12, are supplied, one in each engine room. Either or both may be used. An oil cooler of the surface-condenser type, with oil passing through the tubes and the water around them, is provided in each engine room. The oil passes four times the length of the cooler by means of bridges in the oil heads. The circulating water is taken from either the engine-room fire and bilge pumps or main circulating pumps, and discharges through outboard delivery pipes. Additional oil may be supplied to the forced-lubrication system by an overhead gravitation system from the tanks containing reserve oil. The outlets for oil in the casings are at a high level, so that there is always in the casing wells a large gathering of oil which is at about the same temperature as the shaft.

MAIN AIR PUMPS.

Two independent Blake, vertical, twin-beam air pumps, 14×35×21, are installed, one for each engine room. The suction openings are 12 inches in diameter and the discharge 11 inches. The air-pump suctions take from the lower end of the vacuum-augmenter condensers and water seals (see vacuum-augmenter condenser and Fig. 3).

MAIN CIRCULATING PUMPS.

For each main condenser there is one main circulating pump, centrifugal, with vertical compound engine of B .I. W. design, steam cylinders, 10 inches and 16 inches in diameter; stroke, 10 inches; 42-inch diameter runner. Each pump is of sufficient power to discharge 11,000 gallons of water per minute at about 360 revolutions. Each pump is fitted with pipes and valves to draw from the sea and the main drain and

to deliver into the condenser or overboard through valves in the condenser water chest. Circulating water for oil coolers may be supplied from these pumps.

AUXILIARY AIR AND CIRCULATING PUMP.

For the auxiliary condenser there is installed one simplex, horizontal, combined air and circulating pump of Blake type, 6 × 10 × 10 × 12. This pump has suction pipes from the auxiliary condenser and the sea, and discharge pipes to main feed tanks and to auxiliary condenser. Curves of indicated horsepower are shown in Figure 7.

AUXILIARY AIR AND CIRCULATING PUMP (DYNAMO ROOM).

This pump is for serving the dynamo auxiliary condenser, and is a simplex, horizontal, combined air and circulating pump, 6×8×8×12, of Blake type. Its connections are similar to those for the other auxiliary air and circulating pump. Curves of indicated horsepower are shown in Figure 4.

MAIN FEED PUMPS.

There are two Blake, vertical, simplex, piston, feed pumps, 15×10×15, one in each engine room. They take their suction from feed-tank connecting pipes or channel ways and discharge through grease extractors into the main feed discharge, directly or through the feed-water heaters.

AUXILIARY FEED PUMPS.

Three Blake vertical, simplex, piston, feed pumps, 9×6 × 12, are installed for auxiliary feed purposes, one in each fireroom. These pumps have suction pipes from boiler bottom blows in same compartment, main feed tanks and feed suction pipe. They discharge as auxiliary feed and overboard in same compartment, and to main feed tanks and to fire extinguishers. Curves of indicated horsepower are shown in Figure 5.

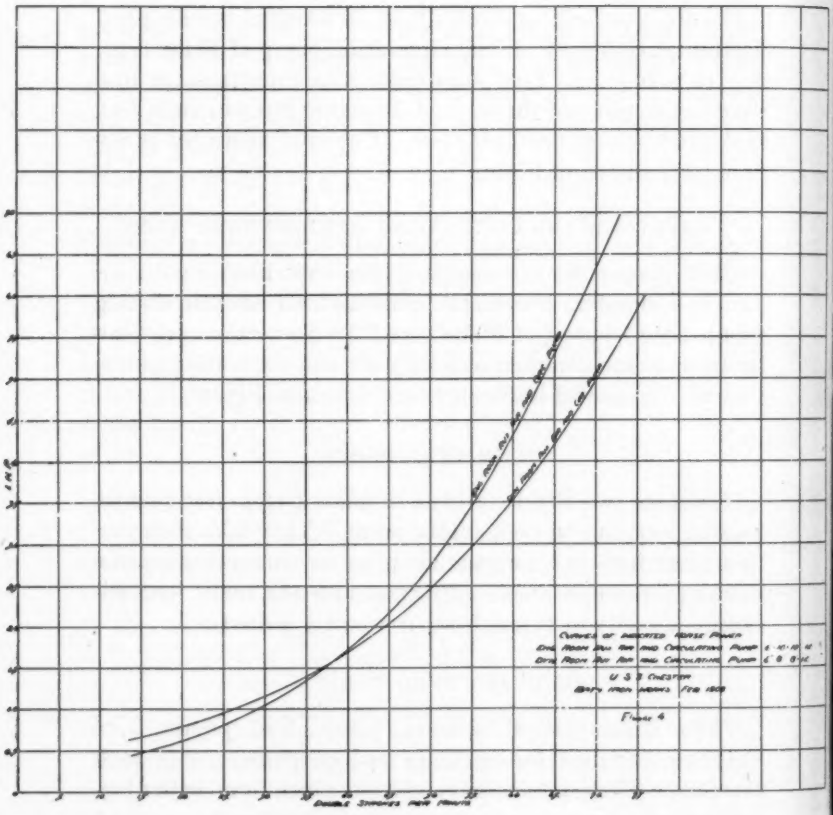
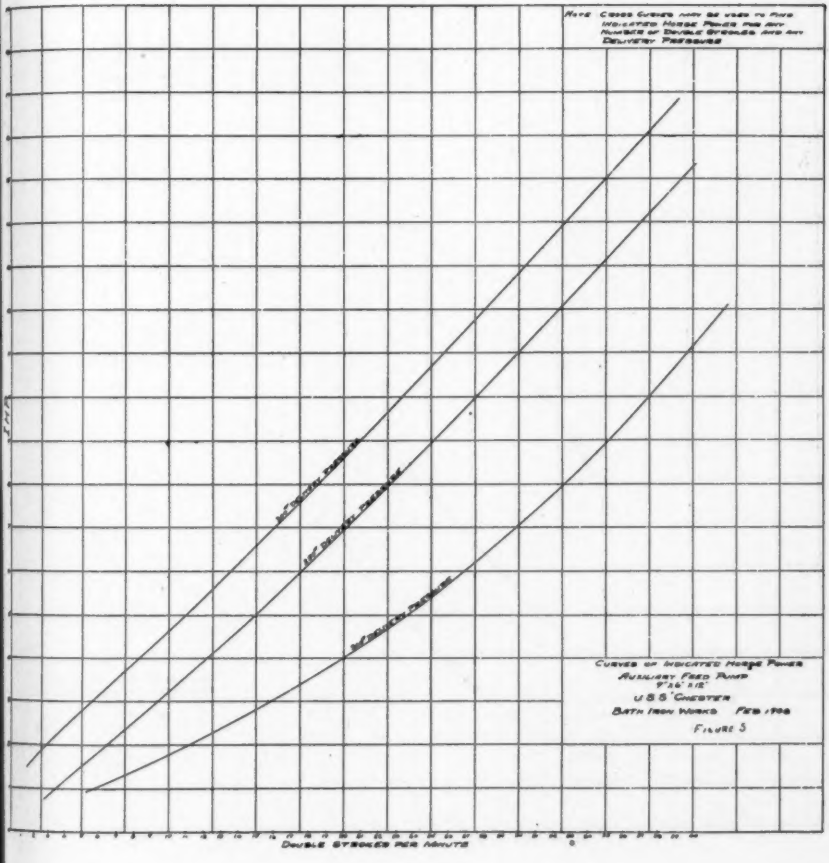
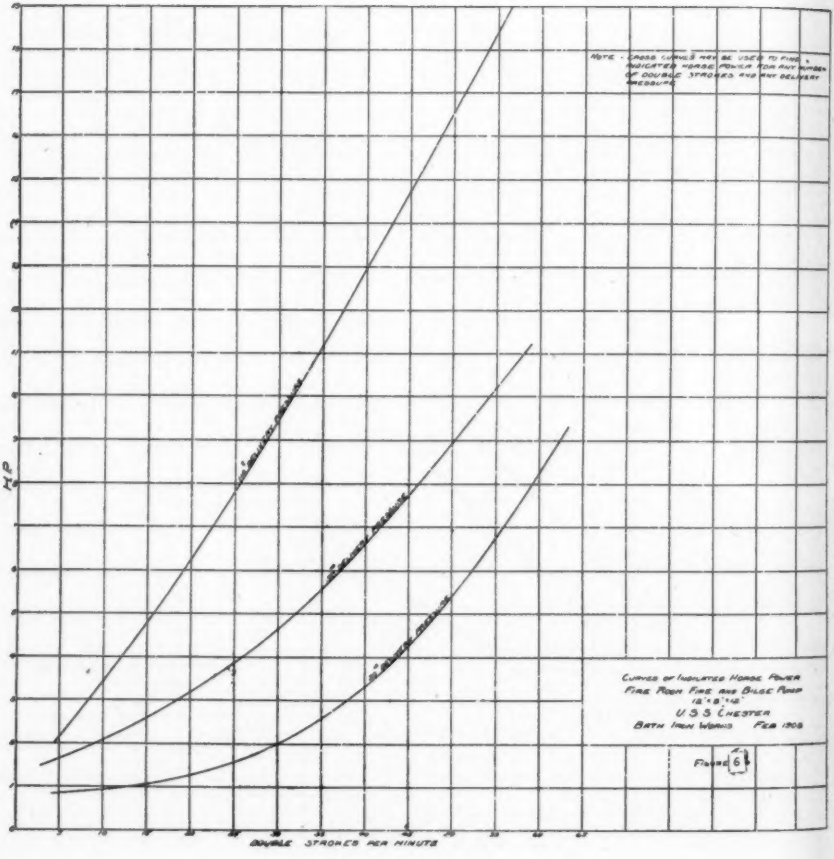

Curves of Indicated Horse Power
Dia. from Air Pump and Circulating Pump
Dia. from Bilge Pump and Circulating Pump
U. S. S. Chester
Built Iron Works Feb 1908
Double Strokes per minute

Figure 4


Note Curves Given may be used to find Indicated Horse Power for any Number of Double Strokes and any Delivery Pressure
At Sea Trial Pressure
At Sea Trial Pressure
At Sea Trial Pressure
Curves of Indicated Horse Power
Auxiliary Feed Pump
9"x6"x12"
U.S.S. Chester
Bath Iron Works Feb 1908
Figure 5
Double Strokes per Minute


NOTE - CROSS CURVES MAY BE USED TO FIND I.H.P. INDICATED HORSE POWER FOR ANY NUMBER OF DOUBLE STROKES AND ANY DELIVERY PRESSURE
I.H.P.
DOUBLE STROKES PER MINUTE
CURVES OF INDICATED HORSE POWER
FIRE ROOM FIRE AND BILGE PUMP
12"x8"x12"
U.S.S. CHESTER
BATH IRON WORKS FEB 1908
FIGURE 6

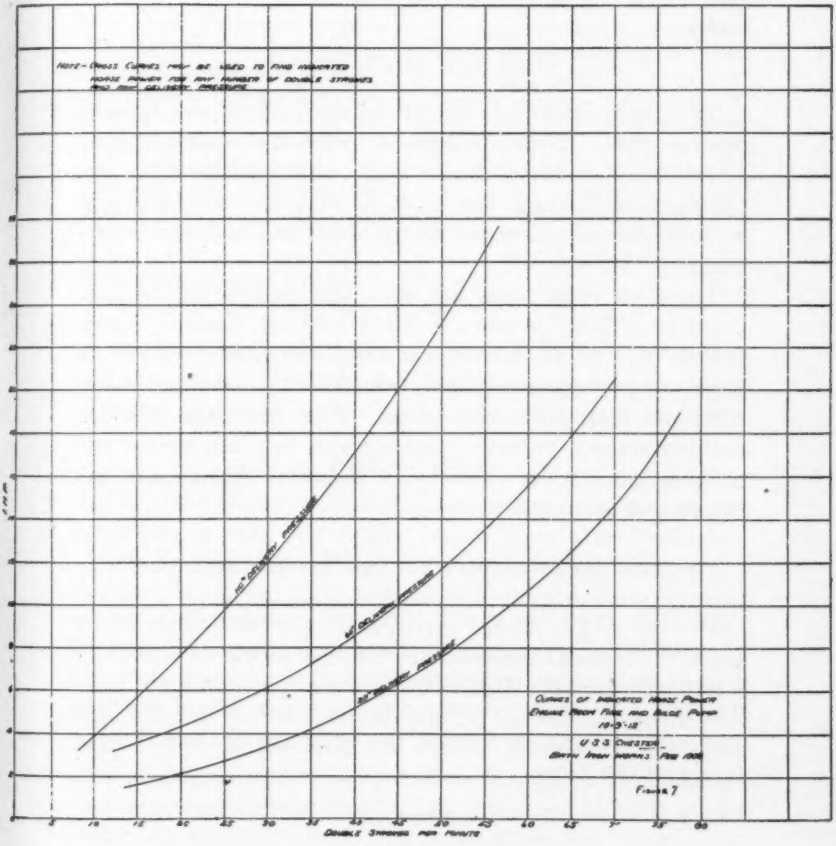

Note - Cross Curves may be used to find Indicated Horse Power for any number of Double Strokes and any Delivery Pressure
Curves of Indicated Horse Powers Engine from Fire and Bilge Pump 19-3-12
U.S.S. Chester.
Both Main Worms Per Inch
Double Strokes per minute

FIGURE 7

RESERVE-FEED PUMP.

One Blake vertical, simplex, piston pump, 10×9×12, is installed in the forward engine room, with suction pipes from reserve-feed water tanks, suction main and filling pipe from ship's side, and discharge to reserve-feed tanks and main feed tanks.

FIRE AND BILGE PUMPS.

Two main fire and bilge pumps are located, one in each engine room. These pumps are vertical, simplex, piston pumps, 10×9×12, of Blake type, with suctions from sea, engine-room drainage and C. & R. drainage manifolds, and with discharges to fire main, overboard and to hose connections.

There are three other fire and bilge pumps, one in each fireroom. These pumps are Blake, vertical, simplex, piston pumps, 12×8×12, having suctions from fireroom floors in same compartment, from sea, from C. & R. drainage manifolds and from hose connections. They discharge into fire main, overboard in same compartment, into ash ejector and to hose connection. Curves of indicated horsepower are shown in Figs. 6 and 7.

PUMPS FOR EVAPORATING AND DISTILLING PLANT.

Of these there are two distiller circulating pumps, 10×9×12, of Blake type, one evaporator feed pump, 4½×5×6, of Blake type, and one fresh-water pump, 4½×5×6, of Blake type. The latter is installed overhead in the trunk, where distillers and reservoir tank are located, the latter are on the bulkhead in evaporator room.

BOILERS.

There are twelve Normand water-tube boilers of the "intermediate" type in the vessel in three watertight compartments, four to each compartment. The following is the boiler data:

Designed working pressure, pounds	250
Test pressure, pounds	400
Ratio of grate surface to heating surface	1 to 46
Length of grates, feet and inches	7–2½
Width of grates, feet and inches	8–0⅛
Per cent. of air space in grates	49
External height, feet and inches	12–5⅝
length, feet and inches	11–6⅛
width, feet and inches	11–4
Number of furnaces	1
Grate surface, square feet	58
Heating surface, square feet	2,670
Total grate surface, square feet	696
heating surface, square feet	32,040
Weight of boiler, with water, tons	19,675
Boiler tubes	cold-drawn seamless steel.
Number of tubes each boiler	986, No. 10 B.W.G., O.D. 1⅞ inches, lengths vary for each row.
Mean height of smoke pipes above grates, feet	63.25
Diameter of smoke pipes, inches	72

The forward and after smoke stacks have two boilers each, and the two middle stacks four boilers each.

Steam gauges on boilers are connected to the water drums.

STEAM PIPING.

The main steam line is arranged in two systems, one on each side of the ship. The branch from each boiler is 5 inches in diameter, and the main steam pipes, which are 5 inches in diameter at the forward boilers, increase in diameter at each successive connection from boilers to 7, 9, 10, 11 and 12 inches, respectively, the last diameter continuing to the handling platform in its respective engine room. There is a stop valve in each main steam pipe forward of the connections from boilers in the after and middle firerooms. Abaft the forward engine-room bulkhead there is a 9-inch cross-connection pipe between the main steam pipes on each side of the ship. An auxiliary steam line is installed, and this line has cross-connection to main steam line in the forward engine room. The auxiliary exhaust line is used on feed heaters and on the steam-gland system. The usual joints, drains, etc., are fitted.

FEED SYSTEM.

A suction main leads aft, gradually increasing in size, from the forward fireroom auxiliary feed pump to the feed tanks in each engine room. From this suction main, branches lead to non-return screw-top valves on engine-room main and fireroom auxiliary feed pumps. There are discharge pipes connecting to and by-passing the feed-water heater from each main feed pump. These pipes unite in a common main leading forward to the firerooms, with branches so arranged and valves so fitted that it may discharge into any or all of the boilers. Each branch has a gate valve, and leads to the main feed-check valve on the boiler. There are gate valves on the main feed pipes to keep the pressure off sections not in use or injured.

Each auxiliary feed pump discharges into an athwartship delivery pipe having branches so arranged that it may discharge into any or all of the boilers in its own compartment. Each branch has a gate valve, and leads to the auxiliary feed-check valve on a boiler. There are also gate valves for keeping pressure off sections not in use, and there is a connection in each fireroom between the athwartship delivery from auxiliary feed pumps and the main feed-discharge main.

WORKSHOP.

The workshop is located over the forward end of the forward engine room, and contains the following tools:

1 Fay & Scott extension gap lathe, 16-inch by 32-inch swing.

1 14-inch Flather screw-cutting lathe.

1 15-inch Hendy shaper.

1 Sibley & Ware 28-inch upright drill.

1 Brainerd universal milling machine, No. 14½.

1 Buffalo combined hand punch shears.

1 Blount No. 3 grinding machine.

1 Buffalo down-draft forge.

1 Workshop motor.

A blacksmith shop is located on the main deck with forge and anvil.

DRAINAGE SYSTEM.

The drainage system comprises three pipe lines, a 6½-inch main drain running between frames No. 52 and 100 with connections to five fire and bilge pumps and two main circulating pumps, a 4⅜-inch inner-bottom main running from frame No. 25 to frame No. 74, connecting to two fire and bilge pumps and with cross connections to main drain, and a 4⅜-inch after suction main with a connection to the main drain and the after fire and bilge pump. The main drain has direct connection with valve at connection to each fire and engine room. The inner-bottom main connects in a similar manner with the inner-bottom compartments and the forward bilges, and the after main with the after bilge. There are two handy-billy pumps located on berth deck, one forward and one aft, and have manifolds, numbered one and two respectively. Connections are taken from these manifolds for drainage and suction. A few of the small compartments have to be pumped out by handy-billy pump-hose suction. All compartment valves have label plates with compartment numbers on them.

FIRE SERVICE.

The fire main runs from frame No. 26 to frame No. 116 under the orlop deck, and is a 4½-inch pipe in the machinery spaces with reduction in size at the ends. The various fire plugs are supplied by risers. There are five fire and bilge pumps connected to the fire main, and the latter has a cross connection to the flushing main at frame No. 76.

FLUSHING SYSTEM.

A 5-inch flushing main runs under the main deck from frame No. 79 to No. 85, and is continued forward as a 2½-inch main to frame No. 44. The main has a direct connection to the distiller-circulating pump and a cross connection to the fire main. All bath rooms, wash rooms, closets and pantries have salt-water connections from the main.

FRESH-WATER SYSTEM.

Fresh water is supplied from the distillers, through the distiller pipe to the hold fresh-water tanks and also by direct connections to the firemen's and machinists' washrooms. Fresh water is also supplied to the hold fresh-water tanks through the fresh-water main by the water-boat connections at frame No. 76. Water is pumped from the hold fresh-water tanks as needed, by the electric pump, located on orlop deck at frame No. 21, into the gravity tank on top of the deck house. From there it runs by gravity into the fresh-water main which supplies by its connections all bath rooms, wash rooms and pantries.

CAPACITIES OF WATER TANKS AND COMPARTMENTS.

Main Fresh-water Tanks.

No.	Location. Frames.	Deck.	Side of ship.	Capacity, gallons.	Capacity, pounds.
1	22–24	Hold	Starboard	1,600	13,333
2	24–26	Hold	Starboard	1,600	13,333
3	22–24	Hold	Port	1,600	13,333
4	24–26	Hold	Port	1,600	13,333
			Total,	6,400	53,332
5	Gravity tank*		.....	1,000	8,333
			Grand total,	7,400	61,665

Auxiliary Fresh-water Tanks.

No.	Location, Deck.	Frames.	Capacity, gallons.	Capacity, pounds.	Remarks.
1	Berth	48–49	100	833	P. O. and mach. washroom.
2	Berth	52–53	150	1,250	Firemen's washroom.
3	Berth	59–60	150	1,250	Firemen's washroom.
4	Berth	63–64	150	1,250	Firemen's washroom.
		Totals,	550	4,583	

Reserve Feed-water Compartments.

Compartment letter.	Tons, F.W.	Gallons, F.W.	Pounds, F.W.	Remarks.
C 96	37	8,605	71,680	Inner bottom.
C 97	30	8,065	67,200	Inner bottom.
C 98	28	7,530	62,720	Inner bottom.
C 99	24.5	6,578	54,880	Inner bottom.
	Totals,	30,778	256,480	

* Located on top of deck house, over crew's galley.

Summary of Capacities for Fresh Water.

Items.	Gallons.	Pounds.
Main fresh-water tanks	6,400	53,332
Gravity tank	1,000	8,333
Auxiliary fresh-water tank	550	4,583
Total	7,950	66,248
Reserved feed water	30,778	256,480
Grand total	38,728	322,728

CAPACITIES OF INNER BOTTOMS AND TRIMMING TANKS (EXCLUSIVE OF FEED TANKS).

Compartment letter.	Location between frames	Capacities, in tons of F.W.
C 95	82–78	26
B 99	78–74	26
B 98	74–70	26
B 97	70–67	19
B 96	67–64	19
B 95	64–60	26
B 94	60–56	26.5
B 93	56–53	19
B 92	53–49	26
B 91	49–45	26

Trimming-tank Capacities.

A 1	Stern to 8	18
A 2	8–18	85
D 3	117 to stern	68

VENTILATION.

The ventilation comprises eight systems, numbered from forward aft. Each is supplied by a single electrically-driven fan, so located that the ducts cut the minimum number of important bulkheads. A supply system is provided for all quarters, storerooms, dynamo room and steering-engine room. An exhaust system is provided to closets. Natural exhausts are provided to dynamo and steering-engine rooms. Coal bunkers have natural supply and exhaust ventilation, the supply through coaling trunks and the exhaust through pipes connected to the uptakes with dampers fitted to all exhaust pipes near uptakes.

ELECTRIC PLANT.

There are three 32-kw. generating sets of 125 volts pressure at terminals. They are of the General Electric type, direct current, compound wound, multipolar. They are located in one dynamo room, on the platform deck just abaft the after engine room. Steam is supplied the dynamo engines direct from the auxiliary steam pipe, and an auxiliary condenser is provided for the exclusive use of these engines.

The dynamo engines are of the vertical, cross-compound, General Electric Company type, encased, and lubricated under pressure. The introduction of oil into the cylinders is guarded against by raised cylinders, and by plates on the tops of the enclosures in which there are soft-packing stuffing boxes for the rods and valve stems to work through.

There are three engines, one for each generator.

Diameter of H.P. cylinders, inches	7.5
L.P. cylinders, inches	12
Stroke, inches	8
Diameter of both piston rods, inches	1¼
Revolutions per minute	400

The following motors are installed:

DECK WINCHES.

No. 1. Starboard forecastle, enclosed, compound-wound, 30 H.P.

No. 2. Port forecastle, enclosed, compound-wound, 30 H.P.

No. 3. Starboard main deck, enclosed compound-wound, 30 H.P.

No. 4. Port main deck, enclosed, compound-wound, 30 H.P.

VENTILATION.

No. 1. Berth deck, center line, open, shunt-wound, 1¾ H.P.

No. 2. Port orlop deck, open, shunt-wound, 1¾ H.P.

No. 3. Engine hatch, enclosed, shunt-wound, 5 H.P.

No. 4. Engine hatch, enclosed, shunt-wound, 5 H.P.

No. 5. Port berth deck, enclosed, shunt-wound, 1¾ H.P.
No. 6. Starboard deck, enclosed, shunt-wound, 1¾ H.P.
No. 7. Port orlop deck, open, shunt-wound, 5 H.P.
No. 8. Starboard orlop deck, open, shunt-wound, 1¾ H.P.

FRESH-WATER PUMP.

No. 1. Port orlop deck, enclosed, shunt-wound, 1½ H.P.

In addition to the above there are also:

One 2-H.P. shunt-wound motor for dough-mixer;
One ¾-H.P. shunt-wound motor for potato-peeler;
One 10-H.P. shunt-wound motor for workshop;
One 1-H.P. shunt-wound motor for dish-washer;
Six ¼-H.P. portable ventilating sets;
Thirty $\frac{1}{12}$-H.P. desk and bracket fans;
Six ⅛-H.P. bracket fans;
and others.

On the lighting circuit there are 640 sixteen-candlepower incandescent lights, 22 arc-lights, two sixty-inch searchlights of about 42,000 candlepower each, one night-signal set, two truck lights and two diving lanterns. The wiring is on the two-wire feeder system. The wiring is open insulation except on main, forecastle, platform and hold decks.

INTERIOR COMMUNICATIONS.

A complete central-station system of telephones is installed, there being 18 telephones. In addition, there are 35 lines of voice pipes. The telephones are a special type of loud-speaking instrument made by the Cory Co. With these instruments three wires are required for each instrument. Instruments exposed to moisture or weather are of the water-tight type. Two ear pieces are fitted, and they are expected to work satisfactorily in exposed places in high winds.

BOATS.

The ship has one 28-foot steam launch, one 33-foot sailing launch, two 30-foot cutters, one 30-foot whaleboat, one 30-foot gig-whaleboat, and one 14-foot dinghy.

ANCHORS.

The following anchors are supplied:

No.	Weight, lbs.	Type.	Stowage position.
1	7,500	Bower	Hawse pipe.
2	7,500	Bower	Hawse pipe.
3	7,500	Sheet	Billboard, port side.
4	3,020	Stern	Main deck, center line, aft.
5	1,540	Stream	Main deck, center line, aft.
6	761	Kedge	Forecastle, center line.
7	402	Kedge	Forecastle, center line.

PERFORMANCE.

FOUR-HOURS' OFFICIAL TRIAL.

Steam Pressure.

	Starboard.	*Port.*
Mean steam pressure at engines, pounds	242.4	246.0
In main H.P. turbine (per gauge)	237.0	240.0
2d I.P. cruising turbine (absolute)	237.0	240.0
L.P. turbine (absolute)	30.2	29.9
Vacuum in condensers, inches of mercury, mean	28.9	28.3

Temperatures. (*Average of one-half hourly observations.*)

Injection, degrees	37.6	36.6
Discharge, degrees	73.0	83.6
Hotwell, degrees	78.2	96.0
Feed water, degrees	222.4	206.0
Engine room, working platform, degrees	51.5	59.0
Firerooms, working level, degrees	42.6	
Smoke stacks, average, degrees	848.0	

Revolutions, or double strokes, per minute. (*Average of one-half hourly observations.*)

Average revolutions, main engines, per minute	616.7	611.92
Pumps, main air	26.0	24.0
circulating	201.0	170.0
feeds, d.s., per minute	46.0	54.0
Dynamo engines	400.0	
Blower engines	349.8	
Speed of ship, in knots per hour	26.522	
Slip of propeller, in per cent. of its own speed based on mean pitch. Shafts are numbered from starboard to port.	(1) 25.71 (2) 25.99 (3) 26.18 (4) 24.34	
Air pressure in firerooms, in inches of water, mean	2.74	

Indicated Horsepower.

Air, circulating and feed pumps, main	328
All other auxiliaries	235

Coal.

Kind and quality used on trial	Pocahontas, hand picked.
Pounds, per hour, main and auxiliary engines, during trial,	38,332
of coal per square foot of grate surface, per hour,	55.08

TWENTY-FOUR HOURS' OFFICIAL TRIAL AT TWENTY-TWO AND ONE-HALF KNOTS.

Steam Pressure.

	Starboard.	*Port.*
Mean steam pressure at engines, pounds	230.0	
In I.P. cruising turbine, gauge	...	192.0
main H.P. turbine, gauge	96.0	93.0
L.P. turbine, absolute	15.0	13.8
Vacuum, in inches	28.3	29.5

Temperatures. (*Average of one-half hourly observations.*)

Injection, degrees	36.0	36.0
Discharge, degrees	63.0	59.0
Hotwell, degrees	74.0	70.0
Feed water, degrees	182.0	205.0
Engine room, working platform, degrees	...	68.0
Firerooms, working level, degrees	54.0	...
Smoke stacks, average, degrees	629.0	

Revolutions, or double strokes, per minute. (*Average of one-half hourly observations.*)

Average revolutions, main engines, per minute	459.71	486.97
Pumps, main air	19.7	21.4
circulating	143.0	156.0
feed, d.s., per minute	28.7	22.5
Dynamo engines	400.0	
Blower engines	180.3	
Speed of ship, in knots per hour	22.782	
Slip of propeller, in per cent. of its own speed, based on mean pitch	(1) 15.66 (2) 16.94 (3) 26.08 (4) 15.15	
Shafts are numbered from starboard to port.		
Air pressure in firerooms, in inches of water, mean	0.7	

Coal.

Kind and quality used on trial	Pocahontas, run of mine.
Pounds per hour, main and auxiliary engines, during trial,	18,063
Knots per ton of coal	2.82
Pounds of coal per square foot of grate surface, per hour	25.95

TWENTY-FOUR HOURS' OFFICIAL TRIAL AT 12 KNOTS.

Steam Pressures.

	Starboard.	*Port.*
Mean steam pressure in engine room	148.0	
In H.P. cruising turbine (gauge)	77.3	
I.P. cruising turbine (gauge)	...	34.6
main H.P. turbine (gauge)	8.0	6.8
L.P. turbine (absolute)	3.3	3.4
Vacuum, in inches	28.4	28.6

Temperatures. (*Average of one-half hourly observations.*)

Smoke stacks, average, degrees	566

Revolutions, or double strokes, per minute. (*Average of one-half hourly observations.*)

Average revolutions, main engines, per minute	254.09	245.29
Pumps, main air	8.6	11.5
circulating	109.4	113.4
feed, d.s., per minute	10.0	...
Dynamo engines	400	
Speed of ship, in knots per hour	12.2	
Slip of propeller, in per cent. of its own speed, based on mean pitch	(1) 12.21 (2) 24.66	
Shafts are numbered from starboard to port.	(3) 19.59 (4) 12.08	

Coal.

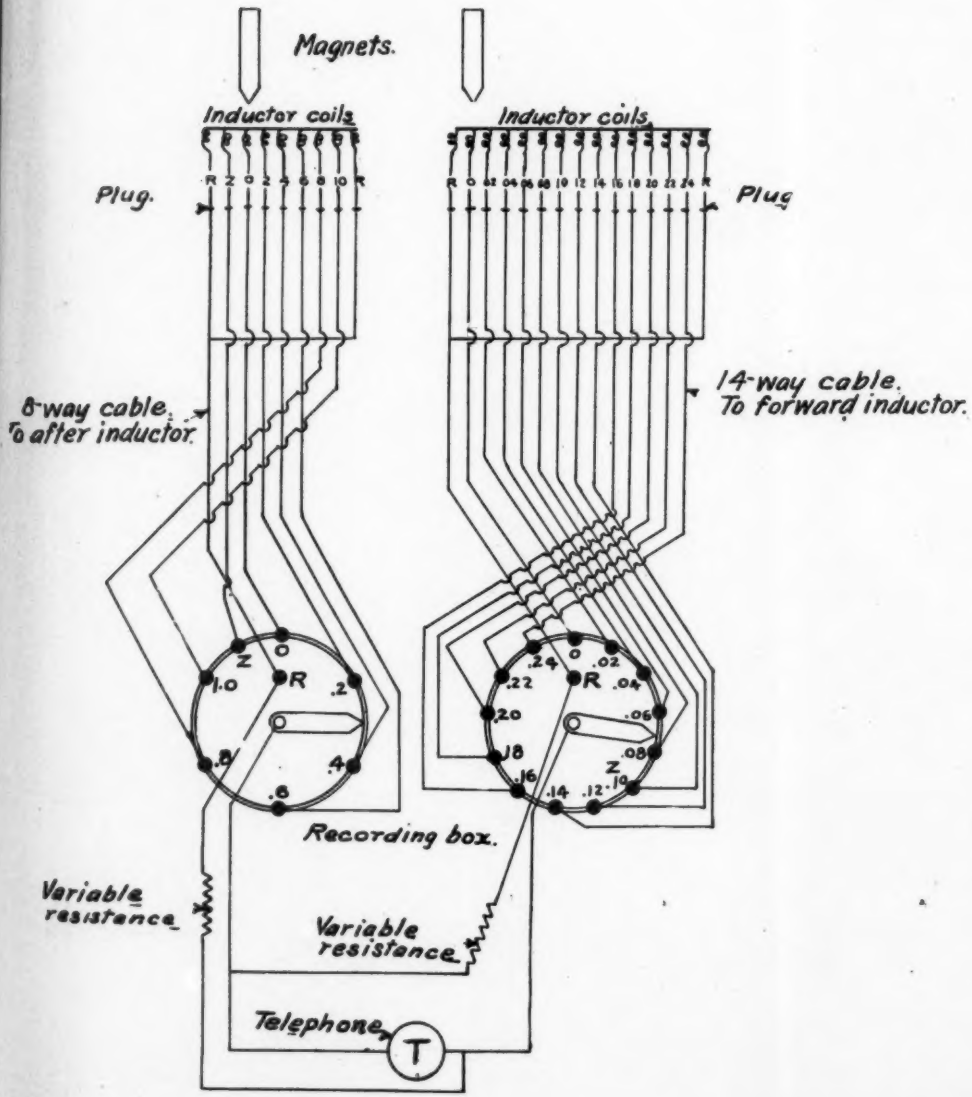
Kind and quality used on trial	Pocahontas, run of mine.
Pounds per hour, main and auxiliary engines, during trial	4,091
Knots per ton of coal	6.68

Deduced Data.

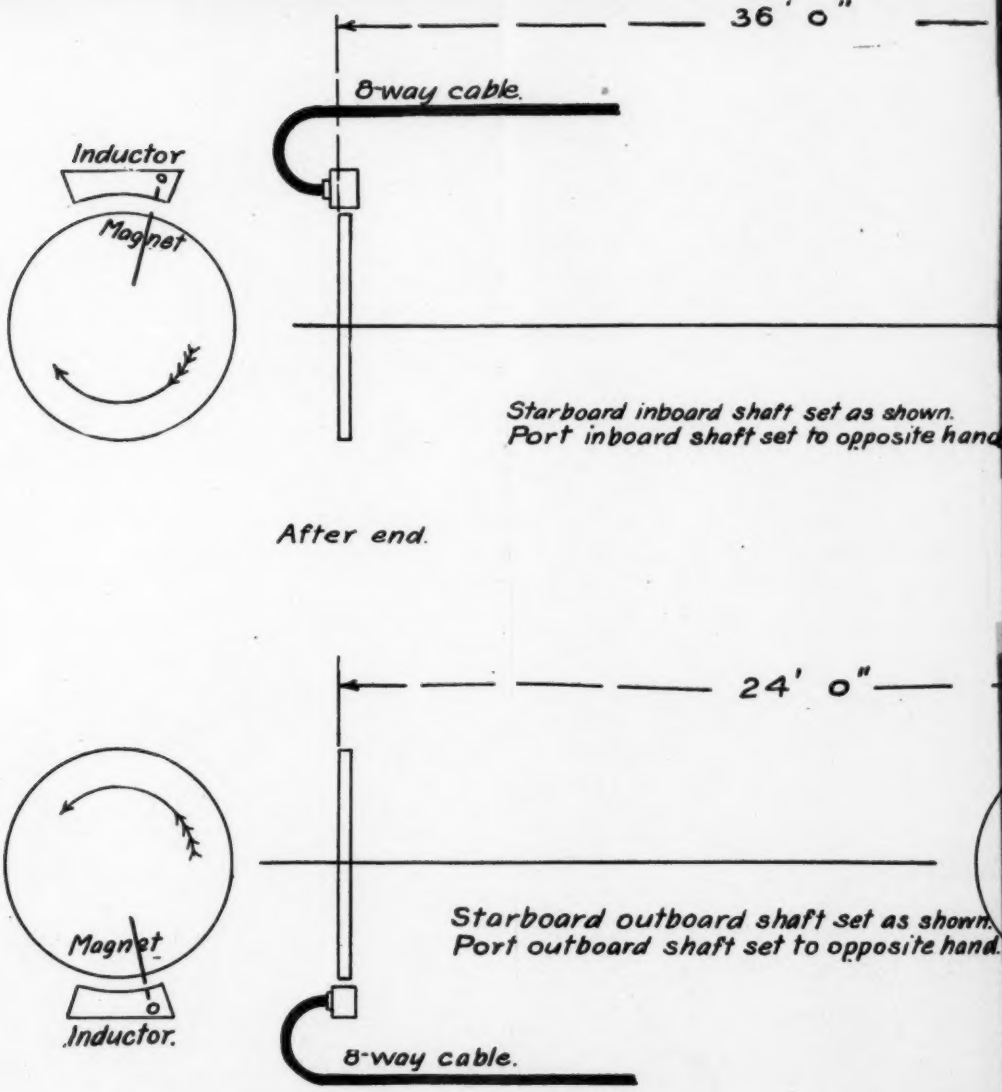
Pounds of coal per square foot of grate surface per hour	17.63

NOTE.—The horsepower on these trials was taken with the Denny-Johnson torsion meter made especially for the vessel. Unfortunately this meter did not give results within reason. The apparatus was installed as shown by the Figure. All parts were very carefully adjusted and were examined during and

Wiring Diagram.

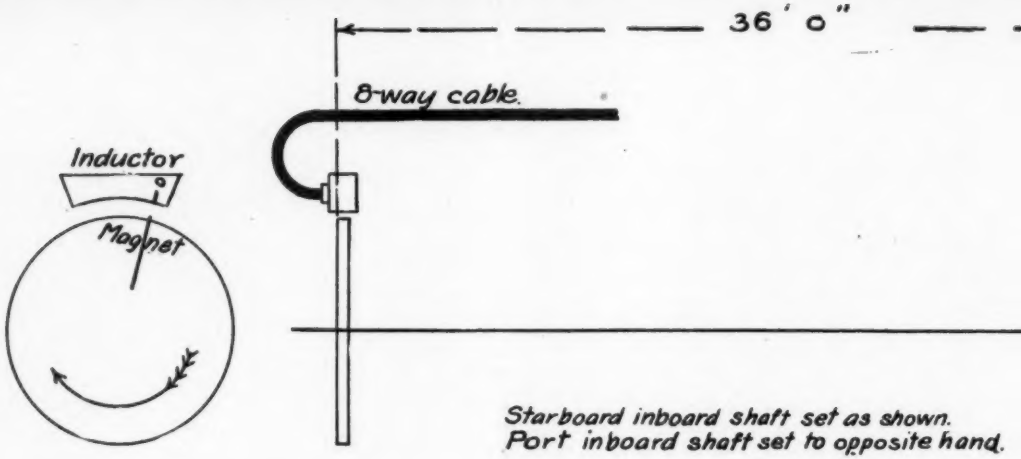


U. S. S. "CHESTER."—



Installation Diagram.

ER."—INSTALLATION OF DENNY AND JOHNSON TORSION METE



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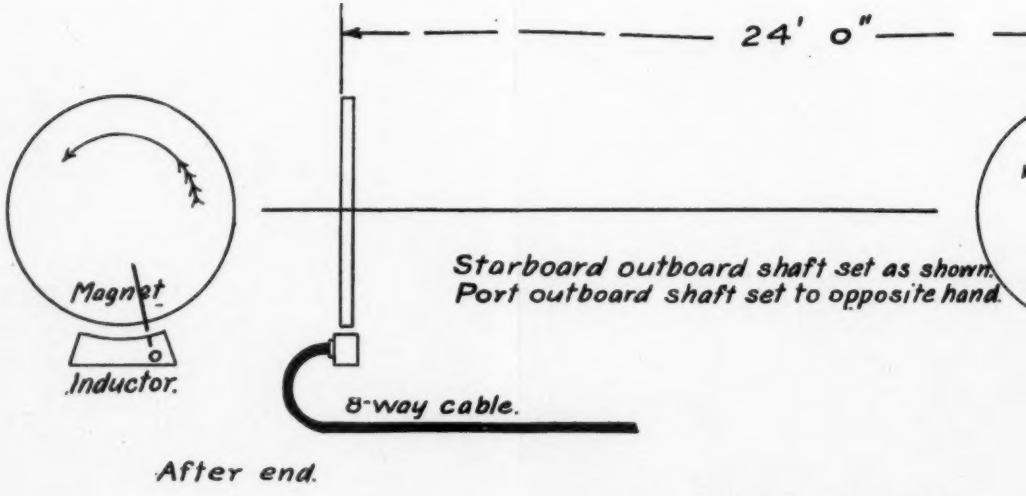
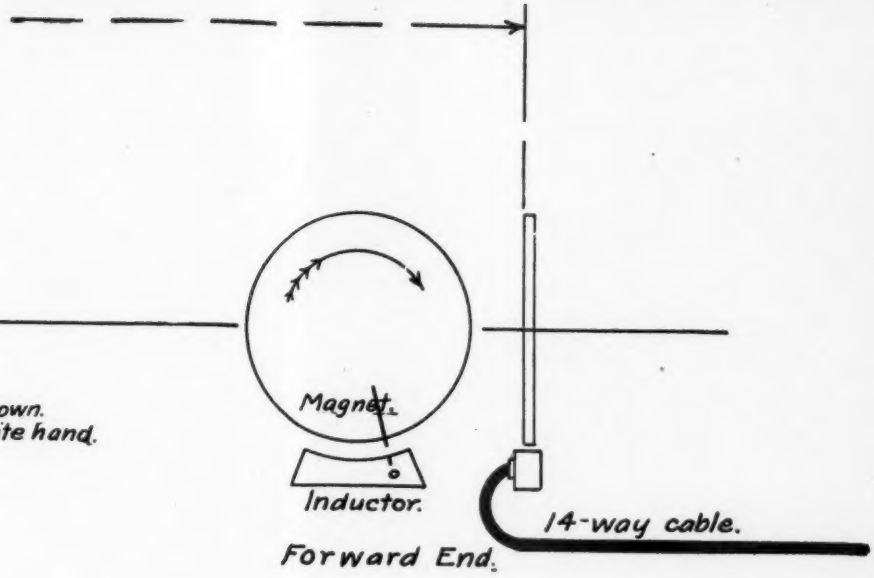
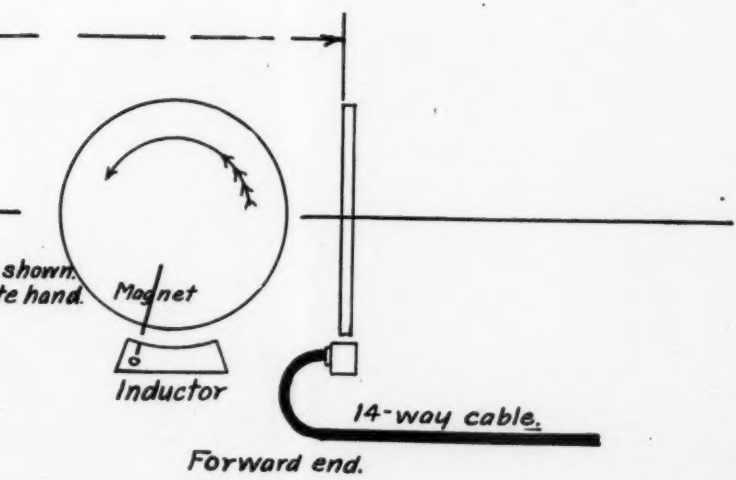


Installation Diagram.

HESTER."—INSTALLATION OF DENNY AND JOHNSON TORSION METE


own.
te hand.
Magnet.
Inductor.
14-way cable.
Forward End.


shown.
te hand.
Magnet
Inductor
14-way cable.
Forward end.

m.

METER.

after the trial to see that nothing had become loose. Also after the trial the two screws on each side of the vessel were alternately towed by the screws of the other side and allowed to revolve, giving the zero era of the machine, which was found to be *nil.* The observations were taken and checked by three different observers. After the experiments were over the meters were sent to the New York yard and tested there. It was found that two of them gave accurate results except at certain points where the wires were broken. The other two did not give reliable results. On examining the recording box carefully it was found that the rheostat coils of these two meters were broken and that various wires in the cable were also broken. The shafts varied so much in horsepower that it was impossible to calculate the horsepower with any degree of accuracy from the results of the two meters that worked satisfactorily.—EDITOR.

A PRACTICAL COMPARISON OF THE ADVANTAGES OF HIGHER CYLINDER RATIOS.

By Second Lieutenant of Engineers C. S. Root, U. S. R. C. S., Member.

An examination of the cylinder diameters of naval engines will show cylinder ratios varying from 1 : 4.75 to 1 : 11.2 in *triple*-expansion engines of ships of war now in commission. This seems to point to a decided difference of opinion among naval engineers in regard to these ratios, and for this reason it is thought that the following account of two moderately long runs of the same vessel with different cylinder ratios may be of interest.

Passed Assistant Engineer E. T. Warburton, U. S. N., in the Journal of the American Society of Naval Engineers (Vol. IX), describes a trans-Atlantic run of the U. S. Steamer *Bancroft* from which the following is taken:

"The *Bancroft* was docked and refitted in September (1896), at the Navy Yard, New York, in ten days, for a cruise on the European station. * * * The *Bancroft* left Tompkinsville, Staten Island, N. Y., September 15, 1896, using both boilers, and arrived at Fayal, Azores, September 25. The dynamo was run about twelve hours, and about 300 gallons of water distilled every day. The vessel started with about 160 tons of bituminous coal on board. Distance steamed, 2,133 nautical miles; time, 10 days 1 hour, or 10.04 days; average speed, 8.85 knots; average revolutions per minute, 124; coal used for all purposes, 102.69 tons; coal per day 10.22 tons; miles per ton of coal, 20.77. There remained in the bunkers 57.5 tons.

"Left Fayal September 28 and arrived at Gibraltar Octo-

ber 4. Strong head winds were encountered for the greater part of the distance. Distance steamed, 1,136 nautical miles: time, 6 days 3.75 hours, or 6.16 days; average speed, 7.69 knots; average revolutions per minute, 129.2; coal used for all purposes, 59.33 tons; coal per day, 9.63 tons; miles per per ton of coal, 19.14.

"Left Gibraltar October 6, and arrived Smyrna, Asia Minor, October 15. Distance steamed, 1,631 nautical miles.

"The coal obtained at Gibraltar was of such very inferior quality that the daily consumption necessarily increased.

"The trip from Tompkinsville to Smyrna (4,900 nautical miles) in 29.5 days, including stoppage of 2½ days at Fayal and 2 days at Gibraltar, at an average speed of 8.25 knots and an average daily coal consumption of 10.3 tons, is not a bad showing for this little vessel. * * *"

In the run described the vessel was equipped with two gunboat or low cylindrical boilers having 2-inch tubes. The total heating surface was 2,686 square feet and the grate surface 87.75 square feet. Her twin-screw, triple-expansion engines had cylinders 13½, 21 and 31 inches diameter and 20 inches stroke; the maximum designed working pressure being 160 pounds per square inch above the atmosphere.

In January, 1906, this vessel was transferred to the U. S. Revenue Cutter Service and her name changed to *Itasca*. During the following winter she was given a thorough overhauling and partial rebuilding. Water-tube boilers of the Babcock & Wilcox type, with 2-inch tubes, were installed. The boilers have a total heating surface of 3,825 square feet and a grate surface of 85 square feet. The matter of cylinder ratios was carefully gone over. New cylinders were designed to give a maximum card factor and minimum terminal pressure while maintaining the same referred M.E.P. that obtained in the old arrangement. The most suitable diameters were found to be 12 and 19 inches for the H.P. and M.P. cylinders. The L.P. cylinders were not changed. The "main-engine" auxiliaries, which included an independent, twin-cylinder, single-acting air pump, remained as before, but a larger elec-

tric generating set was installed, as was also a larger fan for forced draft and ventilation. A feed-water heater was added to her equipment and the maximum steam pressure raised to 215 pounds per square inch above the atmosphere. The propellers remained as before, and the vessel was ballasted to bring her down to her original displacement.

After the trial trips the vessel was taken to the Revenue Cutter Service Yard at Arundel Cove, Md., and hurriedly equipped for sea. She left there on July 20th, 1907, and called at New York, N. Y., and New London, Conn. She coaled at the latter place, and, leaving there on July 28, arrived at Ponta Delgada, Azores, August 7. The data obtained on this part of the voyage were unreliable, for reasons which it is not necessary to enumerate here, and these data will not be included in the figures used hereafter. The *Itasca* left Ponta Delgada, August 9, called at Gibraltar, Marseilles, Naples, Algiers, Funchal (Maderia), and arrived at St. Thomas, Danish West Indies, September 27. Total running time, 765.6 hours (31.9 days). Total distance steamed, 6,817 nautical miles. Total coal consumed for all purposes, 314.5 tons. Average steam pressure, 152 pounds per square inch. An average of 700 gallons of water was distilled every day. The coal obtained at Algiers was of the poorest quality, and it was difficult, at times, to maintain the low speed fixed for the voyage. This coal lasted for upwards of two thousand miles.

The *Bancroft* had strong head winds from the Azores to Gibraltar, and the *Itasca* encountered a gale in the Gulf of Lyons. On each voyage the vessel was handicapped by bad coal for portions of the run. While the *Itasca* distilled more water per day than the *Bancroft*, this was more than balanced by the feed heater. The weather during both runs was uniformly good, except as noted above.

Here we have two long runs at low speeds with practically no change in the vessel, except in the H.P. and M.P. cylinders of the main engines and the addition of a heater, for which a definite allowance can be made. The conditions for comparison seem to be almost as favorable as could be desired.

To sum up the two voyages, we have :

	Bancroft.	*Itasca.*
Ratio of the net piston areas	1:2.4:5.3	1:2.5:6.8
Grate surface, square feet	87.75	85.0
Time out of drydock at beginning of voyage, months,	0	2
Total distance, nautical miles	4,900	6,817
Average speed, knots per hour	8.25	8.9
Average coal consumption, tons per day	10.3	9.86
Water distilled, gallons per day	300	700
Dynamo in operation, hours per day	12	12

In an article published in Vol. XV of this journal, Lieut. D. S. Mahony, U. S. N., has shown that, if the relation between coal consumption and speed follows any law, it is probably as follows:

If rectangular coördinates be used, speed in knots per hour plotted as abscissae and coal consumption in tons per day as ordinates, the curve thus found will differ very little, if at all, from a curve satisfying the equation $y = c + kx^2$. From data in Lieut. Mahony's article is deduced the fact that the actual plotted values of the coal-speed curves of a large number of vessels of the United States Navy did not vary, on an average, from the form $y = c + kx^2$ by more than 3 per cent., the maximum variation being 6.4.

This form of curve will, therefore, be used in making the comparison.

Let y = the coal consumption in tons per day for all purposes at the speed s.

c = the coal consumption in tons per day for all purposes at zero speed, *i. e.*, with all the usual auxiliaries in operation and the engines kept well "warmed up," making, say, 400 revolutions per hour.

k = a constant which must be computed for each vessel.

s = the speed of the vessel in knots per hour.

Then will $y = c + ks^2$.

In the case of the 4,900-mile run of the *Bancroft* we have: $y = 10.3$, $c = 3$, $s = 8.25$. Hence, $y = 3 + .1072\,s^2$. For the 6,817-mile run of the *Itasca*: $y = 9.86$, $c = 3$, $s = 8.9$. Therefore, $y = 3 + .0866\,s^2$.

The value of c was taken from the naval records. These

curves have been plotted and are shown on the accompanying diagram. The difference in coal consumption is seen to be in favor of the later arrangement of machinery, and at 9 knots is equal to $(3 + .1072 \times 9^2) - (3 + .0866 \times 9^2) = 1.67$ tons per day.

The feed heater raised the temperature of the feed 80 degrees Fahrenheit, and, taking the evaporation as 8 pounds of water per pound of coal—which seems ample in view of the quality of coal used throughout the voyage—a simple calculation will show that about one-third of the 1.67 tons of coal saved per day was due to the heater. The remainder of the saving can not be accounted for unless it be credited to the superior economy of the new cylinder ratio of the propelling engines.

The following facts in regard to this particular steam plant are brought out by the above comparison and the trial data of the vessel published in the August, 1907, issue of this journal.

1. The engines with the larger cylinder ratios developed higher power on a slightly smaller grate surface.

2. They have shown greater economy at low speeds.

3. The weight of the engines is a little less, due to the reduction of the H.P. and M.P. cylinder diameters.

The substantial increase in economy due to a small increase in cylinder ratios and steam pressures is again illustrated in the case of the U. S. steamers *Newport* and *Annapolis*. Their hulls are similar, as shown below, both vessels being composite and sheathed with copper.

	Newport.	*Annapolis.*
Length between perpendiculars, feet	167.75	168.0
Beam, molded, feet	36	36
Mean draught, feet	12	12
Displacement, tons	1,010	1,017
Area of immersed midship section, square feet	354	357
Block coefficient	.482	.49
Midship section coefficient	.82	.82
Load water line coefficient	.743	.74

Their engines are as follows:

	Newport. Jacketed.	*Annapolis.* Not jacketed.
Cylinders, diameter, inches	13½, 23½, 36	15, 24½, 40
Stroke of pistons. inches	30	28
Ratio of H.P. to L.P., by net piston areas	1 : 5.67	1 : 7.27

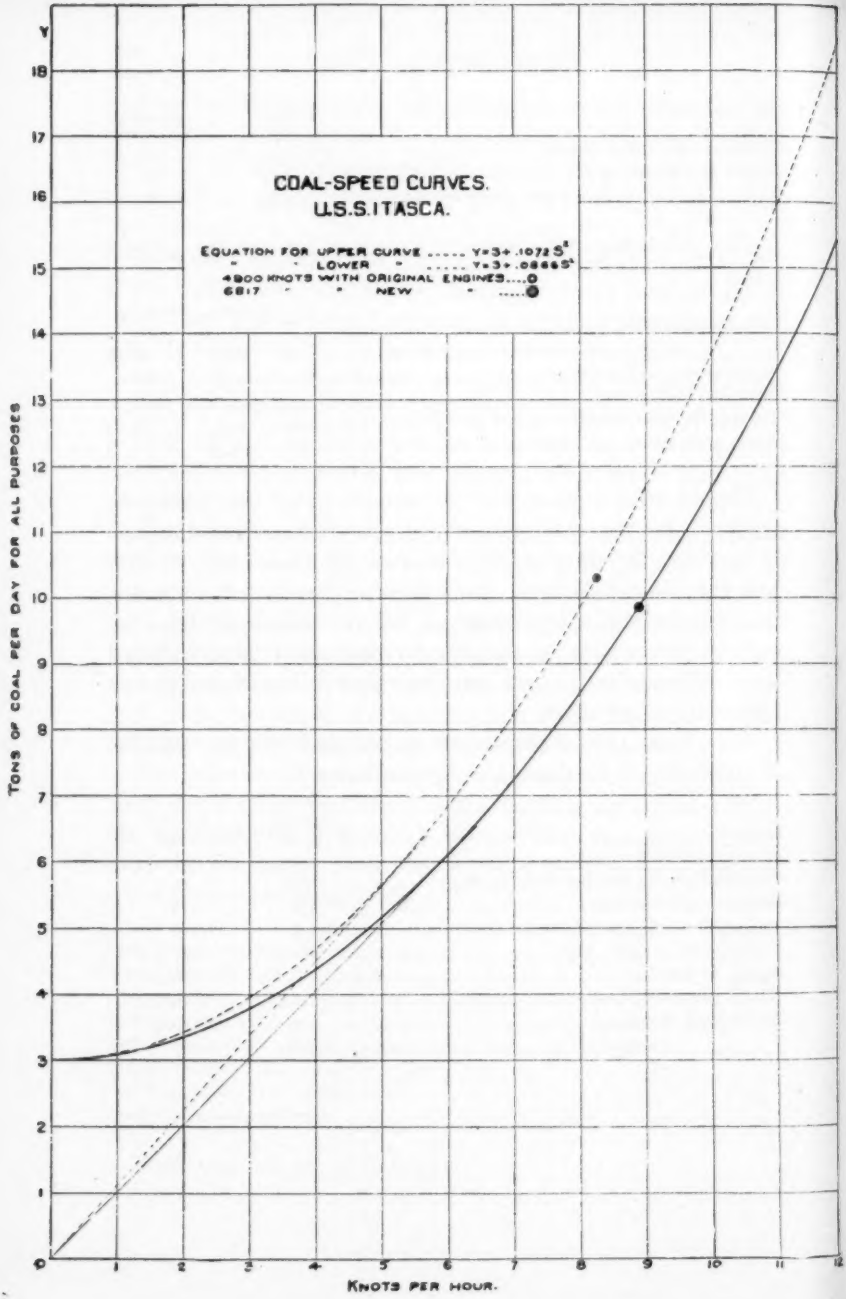
The following data are from cards taken on the official trials:

	Newport.	*Annapolis.*
Pressure at boilers, pounds per square inch, gauge	177	224
M.E.P. referred to L.P. cylinders	42.8	46.58
Piston speed, feet per minute	684.25	686
Indicated horsepower	904	1,217
Terminal pressure of the pv.curve from combined diagram,	20.3	18.6_3
Water per I.H.P., per hour	15.39	13.33

The superior efficiency of the machinery of the *Annapolis* as shown by the water rate above was afterwards maintained in service. Another point indicated by these data is, that had the *Annapolis* been fitted with a 36-inch L.P. cylinder, the cylinder ratios remaining as before, they would have developed power equal to the *Newport* and must have weighed less. These results check with the runs of the *Bancroft* and *Itasca* described above.

Data, from runs made at low speeds, and selected because of similarity of conditions, are given below:

	Newport.	*Annapolis.*
Date	July, 1908.	Aug. & Sep., '08.
Months out of drydock	7	16
Fore and aft sail set, per cent. of time	50	50
Bunker capacity, tons	232	222
Full-load displacement, tons	1,128	1,116
Duration of the run, hours	156	257.3
Speed, in knots	8.1	8.2
Knots per ton of coal	17.4	26.97
Endurance, days	19	30.4
knots	3,722	5,987


COAL-SPEED CURVES.
U.S.S. ITASCA.
EQUATION FOR UPPER CURVE ..... Y=3+.1072 S³
" " LOWER " ..... Y=3+.0886 S³
4900 KNOTS WITH ORIGINAL ENGINES....○
6817 " " NEW " .....●
TONS OF COAL PER DAY FOR ALL PURPOSES
KNOTS PER HOUR.
Y
0
1
2
3
4
5
6
7
8
9
10
11
12
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14
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16
17
18

MODERN ARMOR AND ITS ATTACK.*

By Captain T. J. Tresidder, C. M. G.

The invitation of the Council of this Institution to prepare a paper on the above subject was not accepted by the writer without considerable hesitation, in view of the fact that the material at disposal from most of the possible standpoints was already pretty well used up. A very able paper by Mr. C. E. Ellis, read before the Institution in 1894, brought the history of armor up to the commencement of the period of Harveyed plates; and three years later, an elaborate treatise was published in Italy in the "Rivista Marittima." It is true that the present type of plate was then too young to be included, but several papers have appeared in this country and elsewhere in recent years in which the historical and manufacturing sides of the subject have been more or less exhaustively dealt with and brought up to date.

One point of view, however, appeared still to afford room for an article, namely, the theoretical and analytical; so that has been adopted for the present notes, which, it will be understood, are a mere record of individual opinions based on an experience of much less extent than that of some who may read them.

In looking over some old reports of armor-plate trials, the writer was struck by the frequent repetition of "No penetration" in the column headed "Effect on the Plate." This, of course, meant "No perforation;" but the phrase, seeing that it was used not by tyros but by gunnery experts, suggested that, even in a paper intended for submission to a body of scientific men, it might not be out of place to emphasize the

*Paper read before the Institution of Naval Architects, April 8, 1908.

necessity for attaching precise meanings to the few words constituting the special vocabulary of ballistics.

When two bodies come into collision, "no penetration" is as impossible as perpetual motion. The hardest plate made cannot arrest a drifting snowflake without suffering penetration; for the flake has "work"—in however minute a quantity—stored up in it, and to stop it an equal amount of work must be done by the plate.

What are the agencies the plate can command for doing this work? First, there is F, the mean pressure of the reaction it exerts on the flake.* But pressure alone, even if gigantic, can do no work; it must have distance to act through; and, since the whole plate cannot be expected to move under the circumstances, this necessary distance S can only be obtained by penetration. FS represents the work the plate must do, and FS must equal the work stored in the moving flake, which, though ridiculously small, is not zero. Consequently FS cannot be zero, as would be the case if either F or S separately were zero, which proves the statement.

The word penetration must not be taken to have only the limited meaning of permanent penetration. If penetration does not strain the material of a plate beyond its elastic limit it will be temporary only. It may leave no traces; but, if there has been a collision of any kind, it will have occurred all the same. Penetration is incomplete perforation; perforation is complete penetration. The reference to the snowflake and armor plate is redeemed from triviality by the fact that it forms a striking illustration of the fundamental principle of armor resistance.

As the weapon of the projectile is WV^2, so that of the plate † is FS. It has no other; and all the variations that

* The symbols used throughout this paper and its appendices have the following meaning:
W = weight of projectile, in pounds.
D = its caliber, in inches.
L = its length, in inches.
F = the mean value over the distance of arrest of the end-on pressure, in tons.
t = thickness of plate, in inches.
V = striking velocity in feet per second.
S = distance in which projectile is brought to rest, in inches

† This is a law which governs all plates alike, from the impossible plate of infinite hardness whose F is infinity and S zero, to the impossible plate of infinite softness whose F is zero and S infinity.

are possible in armor resistance are variations of these two factors, although, for any given value of F, considerable variation is also possible in the amount of maximum pressure and the instant of its development.

F, being the mean mutual pressure between projectile and plate, can only increase with the energy of the former up to the maximum capacity of the material of the latter. The stronger that material is the larger can $F S$ be (and, therefore, the higher the amount of WV^2 that can be resisted) for a fixed value of S. On the other hand, the less rigid the plate is, and the more deformation it can undergo without rupture, the greater can $F S$ be (and, therefore, the higher the amount of WV^2 that can be withstood) for a fixed value of F. This constitutes the general principle of which we may now proceed to examine the details.

The resistance of armor plates to perforation by projectiles may be divided into three classes:

(a) Rigid and concentrated.
(b) Yielding and distributed.
(c) Combination of (a) and (b).

In class (a) the molecules of the plate very strongly resist alteration of their relative position, but are incapable of retaining their inter-cohesion when that relative position is forcibly changed. Steel plates that are hard throughout are examples of this class. They present a high resistance per unit of area actually attacked, but do not distribute the work of resistance to perforation* much beyond that area. Their FS relies principally on the F element.

Plates that are tough throughout are examples of class (b). These offer less resistance per unit of area actually attacked, but utilize very largely the resistance of the metal outside that area. In this class of material the molecules less strongly

* Resistance to "racking" is altogether a different thing. It used to be as important as resistance to perforation, but improvements in armor have rendered plates practically secure from failure under "racking" attack, so it need not be taken into account in the discussion of armor resistance proper. It must not, however, be lost sight of in the general design of armored structures, for it may cause failure of the bolts, etc. The more a plate resists with its F factor the more will the bolts be strained in tension; the more reliance is placed on the S factor the more important is it that the bolts should be capable of suffering sudden bending and distortion without breaking.

resist alteration of their relative positions, but are capable of retaining their inter-cohesion when that relative position is forcibly changed to a substantial extent. Their *FS* relies largely on the *S* element. The essential difference between classes (*a*) and (*b*) is not one of strength, nor necessarily one of hardness, but one of structure. Class (*a*) materials must have a crystalline structure; those belonging to class (*b*) should have an amorphous one.

Consider the case of two plates of equal thickness, one a sample of class (*a*) having a breaking stress of 100 tons per square inch, and the other of class (*b*) with 50 tons per square inch; and suppose both to be incapable of cracking and to be normally attacked by the same unbreakable projectile at equal increasing velocities. Which will suffer perforation earliest? Probably the hard plate; for, although it can muster 100 tons per unit called upon, it calls upon so few units that the total force exerted by the shell divided by this number may exceed 100 tons before the same force divided by the larger number of units called upon by the soft plate exceeds 50 tons.

Moreover, all the work stored up in an unbreakable projectile has to be done on the plate, and must be balanced by the sum of the forces necessary to displace each displaced molecule of plate metal multiplied by the distance through which each force acts. Each molecule of the hard plate may take a double force to displace it, but the bulk of the force only acts through the distance necessary to produce rupture, and this will be quite a small distance with a hard plate, and a substantial distance with a soft one.

The best illustration of this principle is seen by the stopping of a cricket ball by a net. If, instead of a net, a fence of ½-inch pine were used to stop the ball, it is not impossible that a fast bowler might smash through it. Yet, comparing the materials, one would expect much more strength in ½-inch wood than in netting. The wood fails because it tries to stop the ball with very small self-displacement: its *F S* is nearly all *F*. The net succeeds because it accepts a large self-displacement; *S* plays the leading part in its *S F*.

So far, on the assumption that the projectile is unbreakable, the balance of advantages seems to lie with the soft plate, apart from the fact that it is not liable to crack, which the all-hard plate is. There are, however, one or two considerations which introduce a practical modification into this comparison. One is that it is not always convenient, and sometimes it is not possible, to permit the substantial deformation the capability of undergoing which, without rupture, is the feature of the soft plate. A more or less rigid resistance is essential, for instance, in the protective armor of many gun positions where quite a small deformation would jam the mounting and put the gun out of action. Under such circumstances an all-hard plate might find employment if we could make one that would not crack. Another modifying consideration is that the distribution of work and the material displacement on which class (*b*) relies take time, and, therefore, are less pronounced advantages when the projectile's energy is principally due to high velocity than when it is more the result of large weight.*

Modern face-hardened plates come under class (*c*). The hard layer adds to the general rigidity, but while by so doing it diminishes *S*, it is doubtful if it adds anything to *F*, although it very greatly increases the pressure at the first instant of impact when the point of the shell, if uncapped, is without lateral support. It alters the shape of the pressure diagram, so to speak, without adding anything to its area. (See Figs. 12, 14 and 15.) As the hard layer does not involve liability to cracking of the whole plate, the hard-faced plate (even against unbreakable shells) has advantages for shields whose substantial deformation would be fatal. Seeing that class (*b*) plates, however, can be made to combine high values of both *F* and *S*, there would probably be but little scope for hard-faced plates if projectiles could not be broken; but against

* A 2.24-inch shell of 6 pounds at 3,000 f.s. and a 12-inch shell of 850 pounds of 583 f.s. have equal energy per inch circumference. A hard-faced thin plate would give good results against the former although small uncapped projectiles are less easily pulverized on a hard face than large ones), but would make a very poor show against the latter. With a strong, tough, homogeneous plate, erected so that it could accept deformation, the difference would be just the other way.

breakable shells they have a great advantage in the fact above alluded to, that they introduce high-stress intensity at the first moment of impact when the shell's delicate point, if uncapped, is very weak. High-stress intensity that is reached at any later stage of impact does not find the point without lateral support, which is the reason it is so important that, in a plate designed to break projectiles there should be no soft layer whatever in front of the hard one.* It was owing to their power of breaking projectiles that hard-faced plates held the field before the general introduction of caps; and, although since that time they continue to hold the field, it is principally to impose upon an enemy the inconvenience and expense of capping all his A. P. shell.

Caps† play such an important part in the present-day attack of armor that it is desirable to devote some space to their discussion. Let us first consider the manner in which an uncapped pointed projectile behaves on impact with a hard face, and then pass on to discuss the purpose a cap serves, and how it serves it.

At the moment of first impact of an uncapped pointed projectile of given weight and caliber on a hard face, an "end-on" pressure, dependent directly on the square of the velocity and inversely on the amount of yielding of the plate, is applied to its point. This pressure it will be strong enough to bear if V does not exceed a certain value, which may be called the first critical velocity. Up to this value of V the projectile needs no cap, because it is strong enough without one. All the work is done on‡ the plate, which receives an indent al-

* A case is remembered of a treated compound plate where the face had good punch-breaking hardness about $\frac{1}{10}$ inch below the surface, which was itself soft. It was perforated by projectiles; it would certainly have defeated if the thin soft layer (which helped the shell like a cap) had been removed.

† The idea of putting a cap on the point of a projectile to save it from fracture on impact with a hard face emanated originally from a British engineer officer, Captain (now Lieutenant-Colonel) English, in 1878. It was suggested by the behavior of a Palliser shot that had been fired against a compound plate accidentally erected with its soft side in front. Captain English designed the first cap that was ever tried, and it gave a successful result, but the matter was allowed to drop for some reason that has not officially transpired. The Russians took the idea up in 1894, and since that time the use of caps has extended and is now almost universal for projectiles intended to perforate hard-faced armor.

‡ The difference between "on" and "by" is important. All the work stored in a projectile must be done *by* the plate that stops it; but the amount done *on* the plate will be less than the whole by the quantity, if any, that is done on the projectile.

most as if had no hard face; this indent may amount to perforation if the plate is thin enough and well held up. The projectile should remain intact.

Immediately V is increasd beyond the first critical value (though it may be by the addition of only a single foot-second) matters undergo a radical change. The initial pressure reaches an amount in excess of the maximum than can be supported without fracture by the projectile's point, which consequently fails and involves the destruction of the whole shell. This, in flying to pieces, absorbs so large a portion of the whole work that it leaves but little to be done on the plate; so the latter suffers to a very small extent, and very much less than at the preceding lower velocity.

As the speed of attack is increased still further the wrecking of the projectile is more and more complete, and the amount of work absorbed by it increases also, but by no means in proportion to the increased total. More and more remains over, therefore, to be done on the plate, which accordingly suffers more and more till at last perforation is effected. This perforation is not in the form of a clean parallel hole, but a rough conical one of great size at the back, from which a large cone-shaped disc is smashed out.

The augmentation of velocity being still continued, another critical velocity—which may be called the third, and is an extremely high one—is eventually reached, when the projectile, though uncapped, is able to stand the initial compression stress, either because of the extra rigidity imparted to its molecules, or because of this combined with an actual reduction of pressure.* It then goes through unbroken and leaves a clean hole.

The nature of the uncapped projectile's failure between the first and third critical velocities may be confidently stated to be the following: A small piece of the extreme point in the form of a double-ended cone is driven back into the head and splits it like a wedge (Fig. 1). This initial split is succeeded

* The writer has a theory on this subject which he had intended for inclusion in these notes, but the intricacy of the argument rendered it impossible for a reasonably brief summary to do justice to it.

by numerous others following each other in the order of the numbers in Fig. 2, maintaining a direction approximately parallel to the rear surface of the originally formed double cone. The idea is that when the point is arrested it causes a surface of cleavage say at 1, 1 (Fig. 2); nevertheless, the point enters the plate and the shell is again arrested as at the points 2, 2, 3, 3, and so on, each time cleaving along a new conical surface, extremely near the previous one at first, and a little more widely spaced later on. The resulting conical laminæ thus intiated break up and fly tangentially to the plate as fast as they form, so that the rear part of the shell is "piled

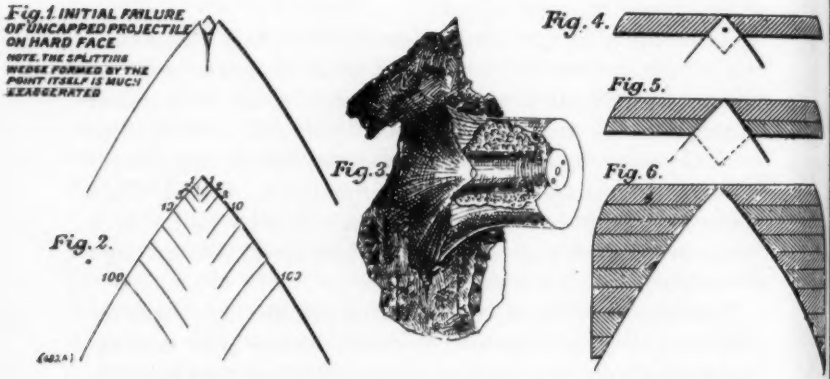


Fig. 1. INITIAL FAILURE OF UNCAPPED PROJECTILE ON HARD FACE.
NOTE. THE SPLITTING WEDGE FORMED BY THE POINT ITSELF IS MUCH EXAGGERATED
Fig. 2.
Fig. 3.
Fig. 4.
Fig. 5.
Fig. 6.

up" on the front part, as in Fig. 3, which was sketched from an actual result.

It will be observed that the mischief originates close to the point, and that the fatal first wedge does its work by bursting laterally the portion of the head just behind it. If this portion were fitted with a reinforcing ring of adequate strength (Fig. 4), the wedge could not be driven back, and the point would be saved. A larger wedge, shown by dotted lines, would then try to burst the head further back, and another reinforcing ring would be required (Fig. 5). But the projectile is larger and stronger here, so the second ring need not be so strong as the first. Imagine this process repeated, of larger

and larger wedges counteracted by weaker and weaker rings, till a part of the head is reached where there is mass and strength enough to need no reinforcement. The system of rings is then like Fig. 6, and, if all the separate rings are united into one wide ring of varying thickness, the dotted line of Fig. 7 results, which shows a section of a Firth cap after

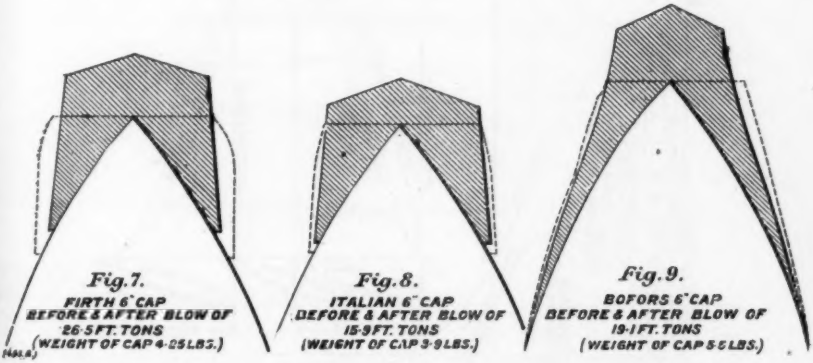


Fig. 7.
FIRTH 6" CAP
BEFORE & AFTER BLOW OF
26·5 FT. TONS
(WEIGHT OF CAP 4·25 LBS.)

Fig. 8.
ITALIAN 6" CAP
BEFORE & AFTER BLOW OF
15·9 FT. TONS
(WEIGHT OF CAP 3·9 LBS.)

Fig. 9.
BOFORS 6" CAP
BEFORE & AFTER BLOW OF
19·1 FT. TONS
(WEIGHT OF CAP 5·5 LBS.)

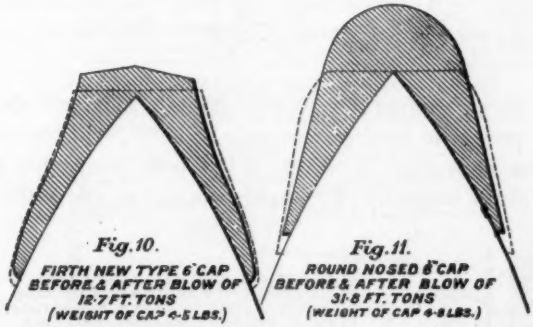


Fig. 10.
FIRTH NEW TYPE 6" CAP
BEFORE & AFTER BLOW OF
12·7 FT. TONS
(WEIGHT OF CAP 4·5 LBS.)

Fig. 11.
ROUND NOSED 6" CAP
BEFORE & AFTER BLOW OF
31·8 FT. TONS
(WEIGHT OF CAP 4·8 LBS.)

being experimentally crushed to the level of the shell's point by a single blow of 26.5 foot-tons. From this it will be seen that the main function of the cap is that of a series of reinforcing rings, whose thickness, and therefore strength, should be proportioned to the amount of reinforcement needed at each part. Figs. 8 to 11 show various other 6-inch caps before and

after being crushed by a single blow of energy proportioned to the cap's design.

Postponing for a moment the consideration of the design

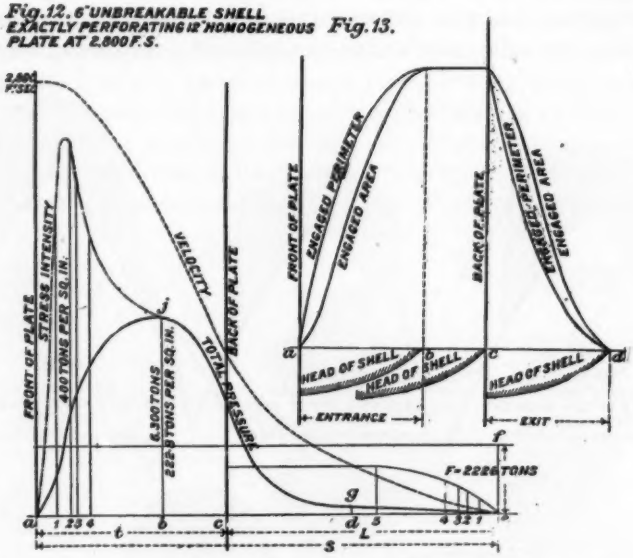


Fig. 12. 6" UNBREAKABLE SHELL EXACTLY PERFORATING 12" HOMOGENEOUS PLATE AT 2,800 F. S.

Fig. 13.

of the cap, it is important to note how its efficiency depends on the projectile having adequate velocity. Three critical velocities have been mentioned; the first being that which raises initial intensity of compression stress above the limit

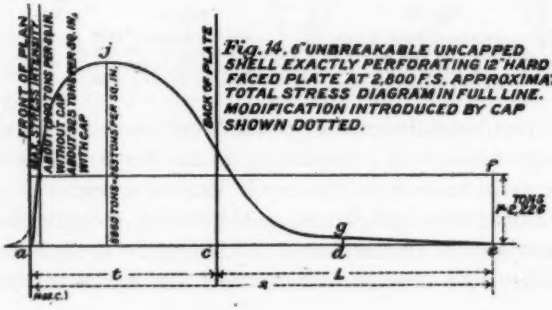


Fig. 14. 6" UNBREAKABLE UNCAPPED SHELL EXACTLY PERFORATING 12" HARD FACED PLATE AT 2,800 F. S. APPROXIMATE TOTAL STRESS DIAGRAM IN FULL LINE. MODIFICATION INTRODUCED BY CAP SHOWN DOTTED.

the uncapped point can stand, and the third that which, either by reducing initial pressure or by raising the strength of the shell, or both, enables the uncapped point to bear the compression stress it is subjected to. (A tallow candle, driven undeformed through a wooden board is an excellent illustration of the third critical velocity). Below the first and above

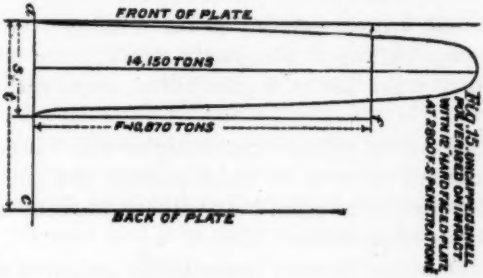


Fig. 15. UNCAPPED SHELL PERFORATED ON IMPACT WITH 12" HARDENED PLATE AT 2000 F.S. PENETRATION

the third critical velocity the projectile needs no cap, because it is strong enough without one. The support afforded by the cap obviously depends on its resistance to stretching in the time available. The shorter that time the more power will be needed to make the cap stretch within the limit of it.

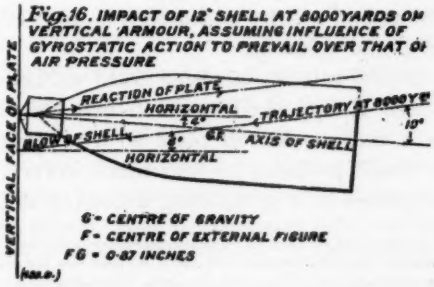


Fig. 16. IMPACT OF 12" SHELL AT 8000 YARDS ON VERTICAL ARMOUR, ASSUMING INFLUENCE OF GYROSTATIC ACTION TO PREVAIL OVER THAT OF AIR PRESSURE

The time concerned is inversely proportional to the striking velocity. Therefore the greater V is, the more reinforcement of lateral strength will the cap afford to the projectile; and, inversely, the smaller V is, the less efficient will the cap be. It is easy to see, then, that there must be a velocity which is

only just high enough to enable the cap to give adequate reinforcement. This may be called the second critical velocity.

Recapitulating, we may state that, in the attack of a hard-faced plate with increasing velocities—

The first critical velocity is the minimum value of V which raises initial intensity of compression stress beyond the limit the point of the uncapped projectile can bear without fracture.*

The second critical velocity is the minimum value of V which enables the cap to adequately reinforce the projectile's point so that it can bear a higher initial stress without fracture.*

The third critical velocity (much higher than the other two) is the minimum valve of V which enables the point of the uncapped projectile to again bear without fracture the stress intensity it is subjected to.

The third critical velocity undoubtedly exists, as otherwise a soft candle could not be driven undeformed through a wooden board,† the explanation of which phenomenon affords room for much interesting discussion. If there is nothing the matter with the plate this velocity may be expected to be a very high one.

The second critical velocity appears to lie, according to quality of plate and quality and design of projectile and cap, between 1,650 and 1,800 f.s.

The first critical velocity has been noted as high as 1,620 f.s. with a 4.7-inch Krupp shell and a 6-inch Harveyed plate; but against a modern Krupp plate with a proper depth of hardness it would probably be very much lower. If, then, a capped shell succeeds in perforating unbroken at 1,600 f.s., or

* The first and second critical velocities may in some cases overlap so that there may be no velocity high enough to break the uncapped projectile and yet at the same time low enough to render the cap inefficient. In such cases a capped projectile is saved from fracture of its point at all velocities. In other cases (dependent on quality of projectile, plate and cap) there may be a small range of velocities that are too high for the uncapped projectile to stand without fracture, and at the same time too low to render the cap efficient. In such cases the projectile will fail to hold together over this range of velocities whether capped or uncapped.

† This is not merely a reference to an old legend that all have heard of, but few have verified. Among the numerous experiments carried out for the purposes of this paper the "candle and board" legend was put to the test, and it was found that marked decrease of deformation in the candle attended moderate increases of velocity.

less, it does not follow, as is often argued, that that velocity is high enough to make the cap efficient; for, with an inferior plate, or a superior shell, it may be that it is low enough to make the cap unnecessary.

We may now consider the design of the cap and its effect upon results. Up till recently the writer held the opinion that the lateral reinforcing action of the cap, already referred to, was the only action of importance it performed. This opinion, however, he has now modified after further detailed study of the problem, very much assisted by the working out of stress diagrams. He still thinks that this reinforcing action, if in large quantity (as in the case of a substitute for a cap consisting of a large wrought-iron plate placed in front of a hard face), would not need supplementing in any way; but it is impossible to deny that it is supplemented in fact, whether it needs it or not.

When the cap and plate first come into collision a high stress intensity occurs for both. The questions that arise are: does the cap (1) yield to this by being flattened, as in Figs. 7 to 11, before the hard face of the plate is disintegrated; or (2) does inertia so support it (as in the case of the candle experiment) that it pierces the hard face without being deformed itself; or (3) do deformation of the cap and disintegration of the hard face go on simultaneously? The probably correct answer is that (1) occurs up to a certain velocity; then (3) as velocity increases; and finally (2) when velocity becomes very high indeed.

If the lowest velocity at which (3) begins exceeds practical fighting velocities, then the cap should be designed as a lateral reinforcer only. That is, it should have, to begin with, one of the forms of the crushed caps shown in Figs. 7 to 11, because it is wasteful of the shell's energy to call upon it to do this preliminary flattening which might better be done in the factory. More than this, the extra resistance to stretching from a state of rest the cap has in virtue of the inertia of its molecules is lost if the crushing is done against the plate, as just when their reinforcing action is called for these mole-

cules are already in rapid motion in the direction stretching gives them.

If, on the other hand, practical fighting velocities enable the cap to act as in (2), or even as in (3), then it should be sharp-pointed, in order to ensure the greatest amount of pressure concentration. The writer sees no theoretical justification for the obtuse-pointed design, and still less for a round-headed design, in either case.

To understand this matter thoroughly it is necessary to go back to the reason for using ogival-headed projectiles at all. Why was a sharp point ever given to an A.P. projectile? The answer is, to concentrate compression stress and give it high intensity, in the hope that the plate would yield thereto before the projectile did. This hope was realized at the commencement, when plates were soft and homogeneous. Then came the steel-faced compound plate which put up the standard of stress-intensity to more than the chilled cast iron projectile could stand.

The reply was the forged-steel shell which brought victory once more to the side of the attack. The defence retorted with the all-steel plate with super-carburized and chilled face, raising stress intensity again to a point at which the shell was the first to give way. Now the projectile gives battle with its nose swathed in a steel bandage to increase its power of bearing-stress intensity, and this expedient, for the time, at least, has restored its supremacy.

It will be seen, then, that from the first the shell has been the one to make power of bearing-stress intensity the issue to be decided; and it certainly never assumed a cap with the intention of distributing pressure instead of concentrating it. A reversion to a flat head would have been the most effective way of doing that. Nevertheless, the cap does distribute pressure incidentally, and it is not impossible that, in view of its small size, it would not give adequate reinforcement, except at a much higher velocity, if it did not. The cap as a reducer of stress intensity assists plate and shell alike, so the shell derives no differential benefit from it in that capac-

ity; but it gives to the shell alone additional strength to bear compression stress, and that is where its advantage to the latter comes in.

If, in addition to laterally reinforcing the projectile's point the cap itself were to disintegrate the hard face of the plate before the shell arrived, another reason would be furnished to explain the reduced liability to rupture of a capped shell. The writer, however, is inclined to think that a velocity high enough to save the soft cap from complete deformation would, *a fortiori*, be high enough to save the shell's point from pulverization. It would, in fact, be not less than the third critical velocity (which, it is thought, must always greatly exceed bare perforating velocity), and then the cap would be unnecessary.

That the kinetic energy possessed by the cap when attached to the shell is not an essential is proved by the fact that a 2-inch wrought-iron plate placed in front of a hard face gives perfect protection from pulverization on impact. This can only act as a lateral reinforcer, for of kinetic energy it has none. The writer's own punching experiments also prove clearly that high velocity, *per se*, is not an essential. The cap on a punch is quite efficient when velocity of impact does not exceed a few feet per second, provided its diameter is not too scanty. The wrought-iron plate quoted above is analogous to a cap with a diameter of several feet, and so should be independent of velocity as well as (as proved) of kinetic energy. Caps of usual form, however, have far too small a diameter to give adequate reinforcement by their resistance to slow stretching, and the writer believes it is for this reason alone that they fail to save the point of the shell until a certain velocity has been reached. If considerably more diameter were allowed to caps their inefficiency at low-striking velocities would probably diminish and possibly disappear.

But the fact that the success of the cap does not depend on it is no justification for disregarding its kinetic energy. If this energy were very great, owing to extremely high veloc-

ity, there can be no doubt the flattening of the cap would not be complete before the occurrence of failure in the plate's face; in such a case the projectile on its arrival would find some of its work done for it. There are reasons, however, for believing that such velocity is not attained in usual practice. Chief among them is the fact that when an uncapped projectile is pulverized on impact—which, it is thought, implies higher stress intensity than is involved in the flattening of any cap—a portion of the original face of the plate some inches in diameter is commonly found to have been driven back intact, showing that it has been able to bear all the stress intensity of the earlier stages of impact, and has only yielded by its peripheral attachment to the plate giving way under the large amount of total pressure that is of later occurrence.*

The writer, therefore, prefers to hold for the present the view that the main function of the cap is lateral reinforcement of the weak point of the shell; that incidentally it reduces stress intensity for both plate and projectile; and that, at current striking velocities, no serious preparatory work is done by it on the plate before the arrival of the shell itself.

Experiments might with great advantage be made to test against each other the two extreme forms of cap, namely, one with a flat head of the greatest admissible diameter projecting very slightly beyond the point of the shell, and the other with an ogival point, like that of the projectile, and projecting 2 inches or 3 inches in advance of it. If the former proved as good as the latter, it would be worth while to try the effect of making it of a stronger material than mild steel; for, although the long-pointed cap must be highly ductile, it does not follow that the flattened one need not be more than moderately so.

All the foregoing remarks have reference to impacts normal to the face of the plate. The subject of oblique impact,

* The diagram in Fig. 14, where striking velocity is about a practical maximum for the present day, seems to suggest a maximum intensity of stress on the plate of no more than 70 or 80 tons per square inch before the arrival of the shell itself.

though very important, is so intricate that considerations of space preclude more than a brief mention of it in these notes.

There are two kinds of oblique impact, of which only one —that of the inclination of the trajectory to the normal to the plate—has hitherto been generally recognized. In this kind the apex of the projectile is practically, if not absolutely, in the line drawn from its center of gravity to the point of impact, and the blow of the shell itself is fairly delivered through its point. In the other kind, which involves still more serious risk of fracture to the shell, its own axis is inclined to its trajectory, while the latter may or may not be inclined to the normal to the plate.

Consider a 12-inch capped shell, loaded and fused, fired at vertical armor at 8,000 yards. Suppose also that on leaving the muzzle it has its axis pointing upwards 4 degrees, its velocity of translation being 2,700 f.s., and of axial rotation 5,400 revolutions per minute. The gyrostatic action due to the axial rotation, though considerably reduced by air friction in flight, may be expected to remain powerful to the last; for, even if the speed of rotation were to lose as much in proportion as that of translation, which is far from being the case, the former would be 3,300 revolutions per minute when the latter had come down to its remaining value for the given range of, say, about 1,500 f.s. The center of gravity of the shell being no more than 0.87 inch in advance of the center of figure, the "righting moment" of the air resistance has only a leverage varying from zero to a maximum of 0.151 inch, and so must be very small (leaving out of account the additional complication of the precessional movement started when the position of a gyrostat's axis is forcibly altered); but, as its influence is at least in the desired direction, we may rely upon the air resistance not increasing the unfavorable angle, and so the worst case will be made out by ignoring it altogether, and assuming that the gyrostatic action is unopposed and retains the shell's axis pointing upwards at 4 degrees when impact takes place and the trajectory is pointing downwards at 6 degrees. Fig. 16 illustrates this con-

dition, and it will be realized that the angle (10 degrees) between axis and trajectory is much more unfavorable for the projectile than a considerably larger angle would be between trajectory and normal to the plate. A "couple" with an arm about 4 inches long is formed by the momentum of the shell acting along its trajectory and through its center of gravity, and the reaction of the plate acting in an opposite parallel direction through the point of impact. This couple must have a powerful cross-breaking effect on the shell.

If the roll of the attacked ship brings its side armor normal to the trajectory at the moment of impact, it increases the obliquity between the axis of shell and the normal from 4 degrees to 10 degrees; and if the roll is in the other direction, and brings the shell's axis into the normal, it increases the obliquity of the trajectory from 6 degrees to 10 degrees. All this is supposing there is no obliquity whatever in a horizontal plane. On the whole, it would appear that truly normal impact at long range is not simply unlikely, but may be actually impossible; whence it is a reasonable inference that the defensive power of armor under the probable conditions of a naval action will be greater than suggested by results obtained with the same striking velocity at short range on the proving grounds.

A KEYLESS LOOSE COUPLING.

By Captain A. B. Willits, Member.

About a year ago the writer devised a novel loose coupling for use in small steamers, launches, etc., where the withdrawal of the tail shaft having a solid flange coupling usually necessitated the removal of the engine as a preliminary. This device has not been patented, although no patent coupling in the records of the Patent Office touched upon the principle involved. Hence its use is free to any one desiring such a convenient arrangement, the patenting of the invention not being considered worth while or necessary. In the wild state of the "market" just now couplings do not seem to be very conspicuously "bulled," and huge fortunes are not usually harassing the inventor of articles, however useful, which never wear out.

The peculiarity of this coupling lies in its being keyless. Its principle is that of the eccentric whose yoke, being prevented, by bolting, from reciprocatory movement, rotates the eccentric absolutely with itself.

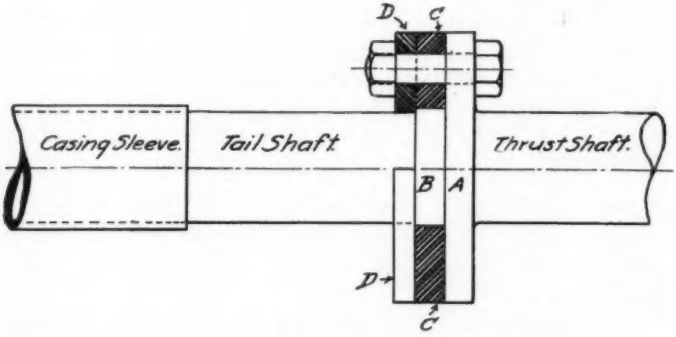
The figure is readily comprehended, and but few words of description are required.

A portion, B, of the forward end of the tail shaft is turned to a larger diameter than the shaft (not to exceed the diameter of the tail-shaft casing or journal at stem bearing) and out of center as much as will give all the eccentricity possible with such increased diameter without quite fairing it, at any part of the circumference, with the tail-shaft surface. This to give at least a trifling lip all around for the purpose hereafter noted.

The loose coupling, C, is turned to an outside diameter exactly equal to that of the solid coupling, A, of crank shaft,

and is then bored eccentrically to the exact amount, and with exactly the same diameter as the eccentric portion B.

Center lines are permanently scribed on the forward end of tail shaft and on the loose-coupling disc before eccentric turning and boring is done, the new centers being in these lines in both cases. This permits the ready adjustment of the coupling disc C on the eccentric B without disturbing the alignment of tail and thrust shaft when bolted up, and with the disc C snugly and properly in place the coupling-bolt holes are drilled or bored and reamed out true and fitted with



body-bound bolts. Two half discs, D, are fitted snugly to the tail-shaft diameter, facing against the lips of the eccentric B and the loose coupling, and holding the shaft from pulling out when backing. These also prevent the tail shaft from turning on its axis around the axis of the eccentric, and these half discs, therefore, must be fitted up and bolted as accurately as are the couplings. To draw out the tail shaft all that is necessary is to remove the coupling bolts from the half discs.

As to how useful this device would be found on large shafting the deponent sayeth naught, but as a neat little device for light work it is commendably cheap and simple.

MODERN TORPEDO BOATS AND DESTROYERS.*

By J. E. Thornycroft.

Since the introduction of the torpedo-boat destroyer, rather more than twelve years ago, such changes have taken place in the construction, and the torpedo boat itself has been enlarged to such an extent, that a review of the developments may be of some value.

Considering the vessels of the British Navy, it will be found that the largest torpedo boats were vessels of about 130 tons displacement and 2,000 indicated horsepower, developing a speed of 23 knots. They were, with one exception, single-screw boats, and were, except in a few cases, fitted with locomotive boilers. The majority of the boats were considerably smaller, and only had a speed of about 20 knots. The only watertight compartments were formed by the bulkheads—watertight flats in the compartments at the end of the vessels not having been at that time adopted. The most powerfully-armed were fitted with one bow and two deck tubes for 18-inch torpedoes and three 3-pounder guns.

At the same time the French and German Navies possessed a large number of torpedo boats of about the same size and power, but differing greatly in design from the British boats. The French design of boat came primarily from the yard of Normand, and the German from that of Schichau. In addition to their torpedo boats, the German Navy possessed a number of much larger and more powerful boats, which were called "Division" boats. These were employed with the torpedo boats, and carried the commanding officers of each division. Although they were vessels of considerable tonnage,

* Paper read before the Institution of Naval Architects, April 8, 1908.

being over 300 tons, they did not develop a much greater speed than the torpedo boats.

The history of the inception of the torpedo-boat destroyer in the British Navy is so well known as to require only a passing reference. The efficiency of machinery which had been fitted to the torpedo-gunboat class being insufficient to enable them to develop a higher speed than the torpedo boats, the British Admiralty decided that vessels of the torpedo-boat type should be built of sufficient power and dimensions to insure their being able to always overtake and destroy torpedo boats with the guns they carried.

The first vessels of this new class, which were called torpedo-boat destroyers, were built by Messrs. Yarrow (*Havoc* and *Hornet*) and Messrs. Thornycroft (*Daring* and *Decoy*). Their trial displacement was about 240 tons, and the power developed was over 4,000 indicated horsepower, which gave a speed of 27 knots. They had a high free board, were excellent sea boats, and were able to maintain their speed in rough weather. Although in dimensions they were somewhat smaller than the German division boats, their greatly increased speed gave them a much higher fighting value, and they were considered such a success that forty more were put in hand during the next two years. It was the introduction of water-tube boilers in these vessels which primarily enabled this high speed to be obtained, and their working was so successful that these boilers were at once adopted by every builder of this class of vessel.

During the next few years the experience gained with them when keeping at sea for considerable periods made it desirable to increase the size and power, and six years after the first boats were built the new vessels that were being put in hand had been increased in size by about 100 tons, and the power from rather over 4,000 to 6,000 indicated horsepower. Their strength and safety had been very much improved by the introduction of watertight flats in the end compartments. The bow torpedo tube had been dispensed with, and their speed had been increased to 30 knots by the employment of high-

tensile steel in their hulls, and improvements in their machinery. The earlier vessels were constructed of steel of the character usually employed in ship construction, but the high-grade steel employed in these later boats had a tensile strength of between 37 and 43 tons, and was so tough as to show an elongation of 15 per cent. on an 8-inch test piece. The employment of this steel was a very important departure, as it enabled 15 per cent. of the weight to be saved in the structure of the hull. The stresses in the hull were about 9 tons in tension and 7½ tons in compression. Perfectly satisfactory results were obtained, and trouble was only experienced in some isolated cases where local stiffening or compensation had been insufficiently considered. During manœuvers, and in making long passages, some instances occurred in which it was thought that greater strength might be advantageous, but the damage sustained was not greater than might have been expected to happen to any vessels under similar circumstances. The fact that all the Japanese destroyers built by British firms made the voyage to the Far East, were at once put into service without any repairs, and went through the war without developing any structural defects, proves that this class of vessel was of ample strength.

After the British Navy had taken the lead, we find that the more important foreign navies quickly followed its example. The new division boats in Germany were built with water-tube boilers, and at once became available as torpedo-boat destroyers. There is, however, considerable difference between these vessels and the British, the German vessels having a very much lower freeboard and drawing more water, besides being fitted with a submerged bow tube.

Mr. Ziese says that the attention of his firm (Messrs. Schichau) is specially directed to designing their vessels to be as low as possible in the water to reduce them to the minimum target. It will be seen from the comparative designs that the typical German vessel (Fig. 9), is much less prominent in this respect than the later British vessels (Figs. 7 and 8). The German vessel is a good deal finer forward,

and the greatest beam is placed further aft; the stern is deep and narrow, quite unlike the broad, flat British sterns. The bridge is kept back as far as possible, being quite close to the forward funnel, one or more deck tubes being placed in front of it and behind the low turtle back. This is, no doubt, a good position for them from a control point of view, but it is thought doubtful if they can be so efficiently worked in bad weather as the British vessels, with their greater freeboard and the torpedo tubes aft.

The destroyers built in France (Figs. 1 to 6) have also a very low freeboard compared with the British boats, and possess quite a special construction of hull. The late M. Normand, and some of the leading French naval architects, were of opinion that much greater strength and security in bad weather are obtained by constructing a vessel with a turtle-back form from one end to the other. This form originated with the Normand torpedo-boats, and was developed to such a degree of exaggeration in the French destroyers that a platform or hurricane deck had to be provided to enable the crew to work the guns and get from one end of the vessel to the other. The hatchway coamings, skylights, etc., are all brought up to this platform, so that the seas can wash over the deck of the vessel—the crew standing above the water. No doubt a considerable amount of weight may be saved by this construction, but it is doubtful if the vessel can be so efficiently worked in bad weather as one with a much greater freeboard. It must not be forgotten that a type of boat may be suited to one class of sea and coast although not successful in another, and the French type may be all that is required for the Channel, but would not do so well for the North Sea or the Atlantic. M. Normand has informed the author, however, that in the latest destroyers of large dimensions which he is building he has abandoned this special construction, and has adopted much more the British type, as will be seen from Figs. 1 and 2, which he has kindly supplied, showing one of his latest vessels. It is understood that this change is not in any way because the construction is unsatisfactory, but simply

Fig. 1.
FRENCH DESTROYER. "CHASSEUR" CLASS.

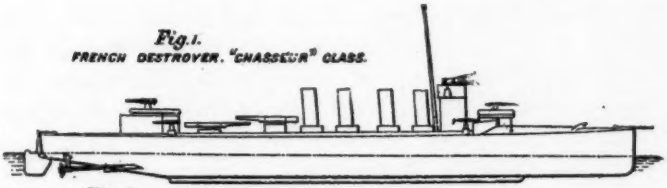


Fig. 2.

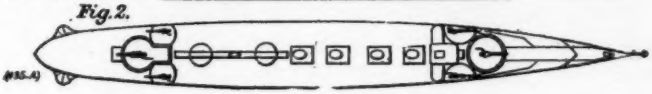


Fig. 3.
FRENCH DESTROYER "BRANLEBAS" CLASS.

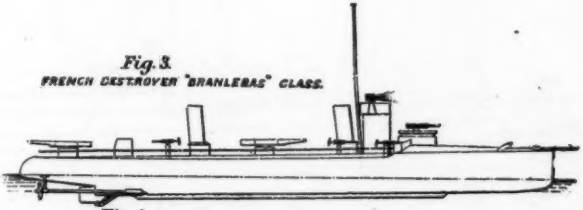


Fig. 4.

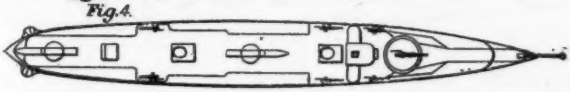


Fig. 5. FRENCH DESTROYER "YATAGAN" CLASS.

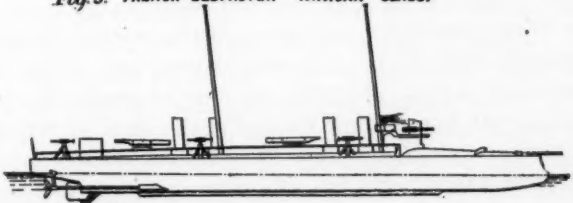
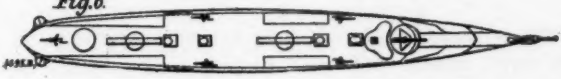


Fig. 6.



that it is less suited to larger vessels, and is more costly. In support of the advantage of what may be described as the British type of vessel, it is interesting to note that besides the Japanese, most navies that have built destroyers have adopted British designs. The British naval authorities have considered the efficiency of destroyers in bad weather to be of such importance that in 1901 it was decided that, in the new vessels, speed should be reduced to the extent of 4½ knots to obtain better sea-keeping qualities and greater strength of hull, and more comfort for officers and men. These vessels were known as the "River" class (Figs. 7 and 8), and while

Fig. 7. BRITISH DESTROYER "RIVER" CLASS.

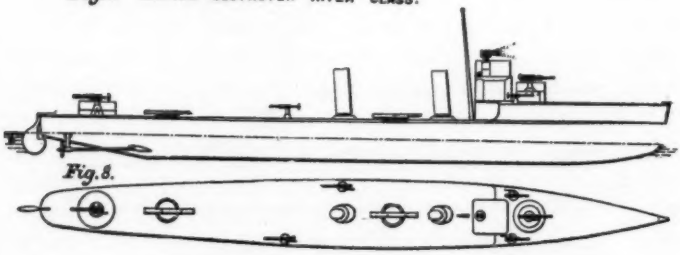


Fig. 8.

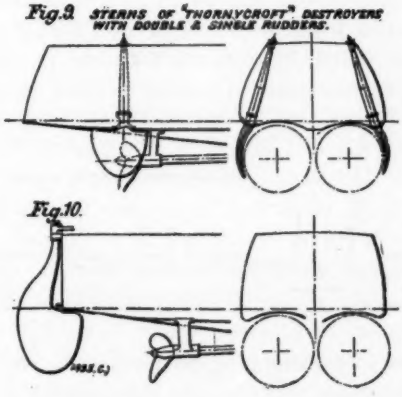
opinions differ as to their fighting value compared with that of the earlier 30-knot boats, it has been conceded that the reduction of speed was too great. There has been no falling off in the demand for high speed in vessels built by foreign navies, and the latest destroyers built for the British Navy have been designed for a speed of not less than 33 knots.

The River class destroyers have a displacement of 525 tons, and develop about 8,000 indicated horsepower, which gives a speed of 25¼ knots. Not only are they of greater freeboard and beam, but have a high forecastle, the deck of which is about 14 feet above the water. This makes them very comfortable and roomy boats, but, of course, much more conspicuous.

Vessels with hulls of this type are now being built for a foreign navy, where they will be required to work in very

open water, and they have also been proposed for the Australian Commonwealth, where similar conditions prevail. The officers who are responsible for this decision have also made the proposal to put the officers' quarters in the fore part of the vessel. The suggestion has often been considered before, but could not be carried out satisfactorily without the extra room provided by the double forecastle.

Reference has been made to the kind of stern adopted in the majority of the German vessels being different to what has been described as the "British type." The form of stern



necessarily largely determines the type of rudder that can be fitted. As in other matters, there appears to be considerable difference in opinion as to the amount of steering control which is necessary. The diagram, Fig. 9, shows a broad stern and double rudders as fitted to the first of the destroyer class, *Daring*, &c., which was copied from the earlier Thornycroft torpedo boats. The arrangement of two rudders, one on each side of the screws, probably gives the best possible steering qualities, both ahead and astern, but has the disadvantage of the complication of two rudders.

It will be seen that the German type of rudder, as fitted by

Messrs. Schichau, is very much more of the ordinary cruiser type of balance rudder (Fig. 11). In some of the fastest of the French boats the rudder has been fitted forward of the screws, but in the later vessels it is arranged like the British boats, with the rudder spindle outside the stern of the vessel. Opinions differ very much as to the advisability of protecting the rudder, which may be done by placing it under the stern or by means of an overhanging counter; but if either of these methods is adopted, it is much more troublesome to unship the rudder than when it is placed clear of the vessel.

The difficulty of steering astern with a single-screw boat is thoroughly understood, and on this account alone there is a strong argument in favor of twin screws for all torpedo craft. The speed at which torpedo craft should be required to be controlled astern is one which must be fixed by naval officers.

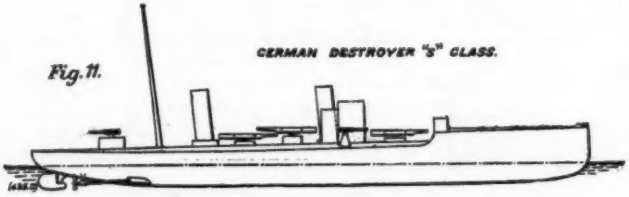


Fig. 11.

While the very best stopping power will be recognized as of the first importance, it is thought questionable if the steering-gear should be required to control the vessel at more than 20 knots astern.

The new 33-knot type of destroyer, of which five have been built and seven are in course of construction or about to be put in hand, is of between 800 and 1,000 tons displacement, and is nominally of about 15,000 indicated horsepower. Experience gained with the experimental vessels *Albatross* and *Express*, intended for a speed of 32 knots, seemed to show that with reciprocating engines it would be very difficult to develop higher speed, and therefore in these new vessels, where a speed of 33 knots was demanded, it was decided, in view of the favorable results that had been obtained with Par-

sons turbines in the several torpedo-boat destroyers in which they had been tried, to adopt them for the new vessels. It is now generally known that, in conjunction with oil-fired boilers, the turbine engines have given results which could not have been obtained without their adoption. The *Tartar*, the fastest of the class, has maintained a speed of 35.36 knots on a continuous run of six hours, or practically 10 knots more than the River class could maintain on a four, instead of a six-hours' trial. While giving every credit due to the turbines and oil fuel for the part they have played in enabling this result to be obtained, it will be agreed that the greatest credit is due to Mr. S. W. Barnaby and the other officers of the firm who have been responsible for the design and building of the vessel. The increase in size over the earlier types which has been found necessary to enable this speed to be obtained with the required radius of action, has been very considerable, the length in the case of the *Tartar* being 272 feet, as against 225 feet in the River class, and the displacement nearly 900 tons, instead of 600 tons. It is worth noting that the strength and proportions of all the individual parts have been kept up to the standard of the River class, and the stresses in the structure of hull do not exceed 8 tons in tension and 6½ tons in compression, these being the limits which have been laid down by the Admiralty as necessary for this type of vessel.

Apart from the coal capacity of a destroyer, the duration of time for which full speed can be maintained depends on the length of time it is possible to run without cleaning the fires, which at full speed, with average coal, is not more than three or four hours. With liquid fuel, stoking is reduced to a minimum, and full speed can be maintained as long as the fuel lasts. The importance of the most skillful attention to reciprocating engines is well known. With turbines, both the number of men and the closeness of attention are very greatly reduced, and it is considered that the difference which has been made by the use of turbines and liquid fuel in these vessels has had as great an effect as the introduction of the

water-tube boilers in the first destroyers. The extent to which destroyers of this power will be adopted by foreign navies is uncertain in view of their very great expense, and in their programs it will be found that vessels of what may be described as an improved British 30-knot class are being adopted.

While the destroyers have been shown to have increased in size and power very greatly from the original type, the torpedo boat has developed almost to an equal extent. In each succeeding order for the British Navy torpedo boats have been made rather larger than their predecessors, until the last reciprocating-engine boats ordered in 1903, which were of 200 tons displacement and 2,900 indicated horsepower, gave a speed of 25½ knots; they carried three 18-inch torpedo tubes and three 6-pounder guns. The latest types of torpedo boats were ordered in 1905, and were at first called "coastal destroyers." They carried the same torpedo armament, were of slightly greater dimensions, but were fitted with turbines and oil fuel, and as far as power and speed are concerned they are practically the same as the first 27-knot destroyers. The adoption of oil fuel, however, has given them a much greater radius of action at full speed.

While the turbines have given excellent results in these vessels, it is a question if equally good results would not have been obtained with twin-screw reciprocating engines and oil fuel, as, while the merits of turbines for larger vessels are admitted on all hands, there is considerable doubt, when powers of less than 3,000 or 4,000 indicated horsepower are required, if the greater simplicity of reciprocating engines is not to be preferred. The necessity of adding a cruising turbine and, owing to the high speed of revolution, of adopting at least three shafts, makes it extremely difficult to arrange the engine room satisfactorily in such small vessels. No doubt with experience it will be found possible to simplify to some extent the arrangement of pipes and auxiliary engines, but in their present form these adjuncts amount to so much that the fitting of the machinery on board becomes an extremely

costly matter, and when it is necessary to open up, an enormous amount of work is entailed. It is thought that it will always be found necessary to put these vessels in dockyard hands if any adjustments have to be made to the machinery, as it will be quite impossible for the crew themselves to deal with adjustments without greater facilities than can be provided on the vessels.

It is believed that it will soon be recognized that the procedure which has always obtained with regard to opening up the machinery after the contractors' trials, and the periodical opening up for inspection, should, with turbine machinery, be discontinued, as not only are so much labor and time wasted, but considerable risk occurs every time the engines are opened up. When once they have been properly adjusted, there is not the same reason for examining the rotors, etc., that exists for looking at the pistons and slide valves of reciprocating engines.

The arrangement of turbines that Messrs. Parsons have thought best for smaller powers, from considerations of simplicity and lightness, is that of three shafts, viz: the high-pressure turbine on one wing shaft, the intermediate-pressure turbine on another and the low-pressure turbine, of more than one-third power, on the center shaft. As the reversing turbine is necessarily a part of the low-pressure turbine, only one shaft is available for astern going, so that from the control and steering point of view the vessel is practically a single-screw one. Some of the earlier turbine vessels did not have very good astern power, but in the later torpedo boats, and particularly in the 33-knot destroyers, the astern-going power has been enormous, the later vessels being capable of making upwards of 25 knots astern.

In the Italian Navy there are excellent examples of torpedo boats of 26 knots speed, fitted with twin-screw reciprocating engines, a considerable number having been built by the firms of Messrs. Pattison and Messrs. Odero, from designs supplied by the author's firm. They have three 18-inch deck tubes and three 3-pounder guns. Although they are

under 200 tons displacement, they are able to withstand heavy weather. For some years all the torpedo boats for the Italian Navy have had their coal bunkers arranged so that they may be used for oil tanks when required. Coal protection to the machinery, however, has been considered of such importance that liquid fuel has so far only been adopted to a limited extent.

The three deck tubes are arranged in the same way as has been adopted in the German Navy, viz: one aft and two forward in front of the bridge and behind the turtleback. It will be noticed that the vessel has a straight keel of sufficient length to enable it to be docked without supporting the overhanging ends. This is a feature which is found most convenient, and has been generally adopted in modern vessels in place of the "cambered" keel fitted to the early torpedo boats. The screws project very little below the line of keel, which is also a good feature where there is any likelihood of the vessels taking the ground.

The possibility of vessels frequently taking the ground in certain navies has been considered of such importance that torpedo boats have been fitted with a false keel in order that the propellers may be protected. The heelpiece, which it was at one time thought desirable to fit under the propeller itself, being found worse than useless, has now been entirely abandoned. This false keel must, however, detract materially from the speed.

The particular coast and condition of service must, of course, be taken into consideration in the case of torpedo boats as well as destroyers, and it is possible that small vessels may be successful in some cases; but it is thought doubtful if, as a rule, good results will be obtained with vessels of much less than 180 tons. It is true that the latest British torpedo boats which are building are nearly 100 tons greater displacement, but they bear about the same relation to torpedo boats of other navies that the 33-knot destroyers do to destroyers of our own and other navies. While questions of cost may not be of the first importance in the British

Navy, there are a number of countries at the present time contemplating the building of torpedo-boat craft where the amount to be expended on individual vessels will be one of the first considerations.

When considering the advantages of employing oil fuel for this class of vessel, its comparative high cost and the difficulty in obtaining it must not be overlooked. The features that strike those who are actually working the vessels most forcibly are the absence of dirt and cinders, and the saving in stokehold staff, the moving of fuel and stoking being effected by steam pumps and pipes instead of stokers and trimmers. With coal-fired torpedo boats it may be taken that the stokehold staff will be quite three times as great as with oil-burning boats; and while with coal firing at full speed it is usually difficult to maintain sufficient steam, in practice it is found that oil-fired boilers are blowing off, or on the verge of doing so; and when the vessel is eased up the boilers are under such perfect control that the safety valves do not lift. The necessity of easing down gradually to avoid blowing off with coal-fired boilers is, of course, thoroughly appreciated.

The evaporative value of oil may be taken as one and a third times that of coal; and while 43 cubic feet of bunker space are required to stow a ton of coal, 38 cubic feet of space are required to stow a ton of oil, so that the equivalent amount of oil fuel can be stowed in 70 per cent. of the space required for coal.

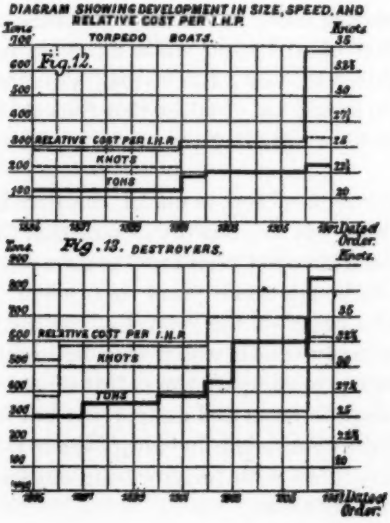
The consideration of cost is not of the first importance in fuel for warships, but it is worthy of note that the most recent oil-tank steamers have not been fitted to use oil fuel on account of the cost, although some years ago, when Sir Fortescue Flannery read a paper on the subject at the Institution, it was expected that many vessels would soon be so fitted.

It is interesting to compare the radius of action of the coal and oil-fired torpedo boats and destroyers; but it is difficult to draw any definite conclusions in view of the coal-burning boats being generally fitted with reciprocating engines and the oil-fired boats with turbines.

It is not proposed to go into the considerations of the relative economies of reciprocating and turbine machinery, as it is recognized that while the turbines have a very high efficiency at full power, at cruising speeds, even when using the cruising turbine, their efficiency is much less than that of reciprocating engines.

In the case of the torpedo boats which have been delivered to China and Japan, it has been necessary to consider their capacity to carry coal for the voyage from Aden to Colombo, and without very special arrangements it is doubtful if turbine vessels could make the voyage; while Messrs. Schichau have informed the author that the vessels which they have built for the Chinese Government actually made the voyage from Port Said to Colombo without taking any coal or water at Aden, a total distance of about 3,700 miles.

It will be noted from the diagrams, Figs. 12 and 13, showing the increase in size of torpedo vessels, that in the case of the torpedo boats the tonnage, speed and price per horsepower have varied in approximately the same proportion,



but as soon as the change to turbines takes place the price per horsepower goes up very considerably. In the case of destroyers, the diagram shows that the price per horsepower also varies approximately in proportion to the increased size of boats until the introduction of the turbines in the 33-knot destroyers, when, owing to the very great power developed, the price per horsepower actually falls instead of increases.

It is admitted that to insure freedom from breakdowns, and general efficiency in service with such small vessels, every possible complication must be avoided in the machinery and mechanical devices; but with torpedo boats, like all other ships, every new class seems to require something added to increase the complication. It is thought that the time has arrived when every effort should be made, particularly where turbine machinery is employed, to reduce the number of auxiliary engines. This suggestion will be better appreciated when it is known that in the latest turbine destroyers there are twenty-one independent steam pumps, besides fans, electric light, and other engines.

An effort has been made by Messrs. Yarrow to attain this end in the destroyers building for the Brazilian Government, by fitting two very large boilers instead of four. The resulting simplification and economy in construction are, of course, great, besides a considerable saving in weight; but the advisability of using boilers in units of upwards of 4,000 indicated horsepower is thought to be open to question.

The policy of some naval authorities to duplicate everything, from the main feed pumps to the syrens, is thought to be a mistaken one. The reserve pumps, or whatever piece of mechanism it may be, that are in duplicate ought not to be required to be brought into operation, and in ordinary commercial engineering do not usually exist. In a battleship, which will go on fighting after receiving a great deal of punishment, the conditions may be different; but the torpedo boat or destroyer either escapes or is damaged to such an extent that no duplication will save it.

It is not within the province of the author to express an

opinion on the relative importance of different types of war vessels; but it is hoped that the large number of destroyers and torpedo boats which are building, or contemplated, by the different Powers at the present time will be considered a sufficient justification for this paper.

NOTES.

THE PRICE OF SPEED IN WARSHIPS.

At the present time, when the financial provisions for the Navy are prominently before us, one is led to reflect upon the continual growth in the size and cost of war vessels, and to wonder where the increase is going to end. The cost of the old *Dreadnought* in 1875 was about £55 per ton of displacement, the cost of the 1907 battleship of that name just over £100 per ton of displacement, and while the cost per ton has thus nearly doubled, on account of the increase of size, the total cost of the ship has trebled. The price of the raw materials which go to make the finished ship has, we suppose, on the whole, not materially altered in this period, and the greatly increased cost per ton is thus mainly due to the increase of the amount of labor which is put into the material. The successive improvements which have taken place in machinery have been in the direction of obtaining a greater output for a given weight, and this has inevitably meant more costly methods of production. It is not necessary to dwell on this point, instances of the truth of which will immediately occur to anyone who thinks for a moment on any one of the numerous mechanical appliances which go to make up a modern warship; but, as a specific instance, we will only ask the reader to reflect upon the amount of labor which is put into a water-tube boiler weighing, say, 10 tons, compared with the amount of labor required in a cylindrical boiler of the same weight. The increase in cost, both total and per ton, may all be attributed to increase of speed in one form or another. The speed of the vessels has been steadily increasing, necessitating higher-powered machinery, and in order to obtain the increased speed without unduly increasing the

power, length of ship and, therefore, displacement must also be increased. Speed of firing the guns has increased, leading to more elaborate and costly gun mountings, and a whole host of subsidiary appliances for handling the ammunition with a facility corresponding to the rapidity of fire; and, lastly, the increase of muzzle velocity of the projectiles has necessitated improvement in the armor so that the same weight of it shall have correspondingly greater resisting power.

The study of this process of evolution which is still going on, the various factors in it, and the way in which they react upon each other, is very fascinating, but on the present occasion we desire to limit attention to the question as affecting one class of war vessels—torpedo craft. The problem in this class does not involve the same complications as in the cruiser or battleship, since armor does not enter into the question at all, while the weight of armament is a small proportion of the displacement, and is governed mainly by considerations of stability and space. The evolution of this type of vessel has, therefore, been almost entirely in the direction of increase of speed, and though some of the advance has been due to lighter hulls, as a result of the employment of high-tensile steel, the main factor has been the successive improvement in the propelling machinery. The *Lightning*, the earliest vessel of the type, in 1877 attained the "unprecedented" speed of 17 knots, and was followed by a number of second-class torpedo boats of small displacement and about the same speed, some of which were intended to be carried on board battleships and cruisers. They had special arrangements for filling their boilers with hot water from the boilers of the parent ship through a hose connection on the vessel's side, with the idea that the boat could be lowered into the water and steam raised in a very short time and the boat despatched to deliver an attack on an enemy not many miles distant.

The possibilities of circumstances arising in actual warfare for such a use of these boats without hampering the movements of the parent ship was seen to be remote. The additional "top hamper" which the carrying of them entailed

was objectionable; they were extremely frail and liable to damage in the operations of hoisting and lowering; they were not very seaworthy and, of course, could not be lowered except in smooth water, and they consequently soon ceased to be carried. Though torpedo-dropping gear is still fitted in the larger steamboats carried on board big ships, it has never been seriously proposed to return to a small torpedo boat carried on board. These boats were followed in the eighties by a number of first-class torpedo boats which, as they were capable of keeping the sea in moderate weather, may be considered as the real starting point in the line of sea-going torpedo craft. Their trial speeds were about 20 knots, and their indicated horsepower varied from 700 to 1,500. The latter of these have in the last year or two been reboilered with water-tube boilers in place of the locomotive boilers with which they were originally fitted. Following these, in the early nineties, came the larger boats *Nos. 91*, *92*, &c., the first to be fitted with water-tube boilers. They displaced about 120 tons, the indicated horsepower was about 2,000, and the speed 23 knots. The possibilities of the water-tube boiler had for some time been under observation, and the great advantage which the small-tube or "Express" type gave in point of steam-giving capacity on a small weight made possible a large advance in size and speed, and the torpedo-boat destroyer was evolved. Thenceforward torpedo craft became divided into two distinct classes—the torpedo boat proper and the torpedo-boat destroyer—and we need only, in the course of the present article, follow the development of the latter. The first torpedo-boat destroyers had a speed of 27 knots on trial with about 4,500 indicated horsepower, and they displaced about 250 tons. As might be expected in vessels so large a step in advance of their predecessors, they did not live up to their trial performance on service. Following these, in the closing years of the last century, came the 30-knot boats, in which the displacement was further increased to about 360 tons and the indicated horsepower to 6,000. Up to this time it was the custom to specify that the trials should be run car-

rying a certain load on board, and this load gave to the boat a displacement less than it would have on service, and, as in the case of the previous class, the speed fell off by two to three knots after the boat was commisioned. In the three vessels, *Express*, *Albatross* and *Arab*, tried about the same time, an attempt was made to exceed the previous results by two or three knots, but the results were disappointing. The displacement in these boats was increased to about 450 tons and the indicated horsepower to 7,500 in the case of the *Albatross*, to 9,000 in the case of the *Express*, and it almost appeared that the limit of power had been reached with reciprocating engines of the type required in destroyers. As the result of experience with some of the 30-knot boats at sea it was deemed necessary in the "River" class which followed to increase the scantlings of the hull, and the displacement was increased to about 600 tons. The indicated horsepower was not advanced, remaining at 7,500, consequently the speed was not so ambitious, but a departure was made in running the trials of these boats at their seagoing displacement. They all attained their designed speed of 25½ knots easily, and have maintained it on service, and except in dead smooth water they are, on account of their size, superior in speed to any of their predecessors. In the meantime the turbine was being steadily developed, and the *Viper* had shown that with this form of propulsion speeds were possible which from previous experience seemed out of reach with reciprocating engines. The experiments with oil fuel at the same time showed that by this means steam production could be increased, and it was a logical conclusion to combine the oil-fired boilers with turbine engines, so that the latter could take full advantage of the increased capacity of the former. The result was the "Tribal" class, where the displacement is increased to nearly 900 tons and the horsepower to 15,000. The combination of oil fuel and turbines is still further to be tested in the *Swift*, now nearing completion, where the designed speed is 36 knots, which is estimated will be obtained with 30,000 horsepower, and the displacement is no less that 1,800 tons.

The preceding sketch of the development of the destroyer is necessarily brief, and some details have been omitted, but it serves to show at what price speed has been obtained. Except in the case of the *Amaxon* and the *Saracen* of the "Tribal" class, and the *Swift*, which carry 4-inch guns, none of these destroyers carry anything bigger than a 12-pounder, and as regards torpedo armament there is little to choose between any of them. The larger vessels have, of course, better sea-keeping qualities, and higher possible speeds in rough water; but apart from this practically the only advantage gained by the increase in size has been that of speed. From the trial results of the "Tribal" class the *Swift* should reach her 36 knots, providing propeller difficulties do not intervene, and it is not difficult to predict what still further increase in speed would involve. To get 40 knots would mean a vessel of 3,000 tons displacement with about 55,000 horsepower. The cost of the *Swift* is given in the estimates as a quarter of a million; the cost of the 40-knotter would be nearly half a million. It may reasonably be asked, are we getting an adequate return for the outlay on these vessels, and is the increase in speed which has been obtained sufficient justification for the very great increase of size?

It appears difficult as the size and speed increases to increase the fuel capacity in proportion, and consequently the price paid for speed is not only the increased monetary cost but a diminution of the radius of action. In a previous article—see "The Engineer" of January 10th—we pointed out that the "Tribal" class compare unfavorably with the earlier 30-knot destroyers in this quality. In the *Swift* the deficiency is even more glaring. The oil capacity of this vessel is given in the estimates as 180 tons, which at full speed will give a radius of action of under 300 miles, while at 13 knots it will be under 1,000 miles. Possibly provision is to be made for additional stowage above the 180 tons which is the capacity at load draught, otherwise it is difficult to see what possible use a craft with such a limited radius of action can have. The results which have been obtained are, as we pointed out in

the article previously referred to, very gratifying; much valuable experience has been gained, and in this respect the vessels so far completed have fully justified the expenditure upon them. It must, however, be patent to every intelligent observer that we have in the later vessels reached a point, if we have not already gone beyond it, where the gain in speed is no longer commensurate with the cost of obtaining it, both in money and diminution of radius of action, and we shall be surprised if the sixteen new destroyers to be commenced under this year's program do not show that this fact has been appreciated.—"The Engineer."

UNDER-WATER ATTACK OF SHIPS BY GUNFIRE.

As a result of the trials against the *Hero*, the British Admiralty is now about to undertake a series of experiments with the object of ascertaining whether the system of artillery attack offering the greatest prospects of success is not one which aims at placing high-explosive shells below the actual waterline of the vessel attacked; and if the result of the experiments should be to prove that such a system is a good one, it will at the same time be obvious that the best place for the main armor belt of the attacked ship is rather in the high than the low position.

The trials, which are to be carried out on the obsolescent battleship *Revenge* by the staff of the Whale Island Gunnery School at Portsmouth, have been decided upon as a result of the sinking of the *Hero* in the trials to which reference has already been made. The *Hero* was fired at on four separate occasions by battleships and armored cruisers of the Channel Fleet, and after the first bombardment she sank in about twenty-five feet of water, so that all her upper works still remained visible. After the firing, the ship was visited by a large number of officers and gunnery experts, but their examination utterly failed to show any reason for the vessel sinking. No armor-piercing projectiles were used in the trials,

and the thick protection of the *Hero* was unperforated, while, so far as could be ascertained, no shot had entered above the belt and been deflected through the bottom. This could hardly have been the case, as the protective deck also was unperforated.

The theory put forward to account for the vessel going down is that a shell filled with a high-explosive charge struck the water some distance short of the ship, descended some feet below the surface of the water, and finally brought up against the unprotected side below the bottom edge of the waterline armor belt. The idea was put forward by a non-gunnery officer, and was at first scouted by the experts, who, as it happens, have made little if any study of the questions affecting ricochets.

Now, however, the theory is to be put to the test. The battleship *Revenge* is to take out to sea a specially constructed target, which will have a large proportion of its area under water. Firing will be carried out at various ranges, from 1,500 yards upward, and at each range a series of shots will be fired, the object being to discover how far short of the target the sights must be adjusted to insure the shot striking at a sufficient distance below the waterline to escape contact with the main belt of armor.

If the experiments are successful, that is, if they show that this method of under-water artillery attack is feasible, there is no doubt but that it will be fully developed; for the effect of a high-explosive shell striking below the water level would be much the same as that of a torpedo. Even if such a shot did not sink the vessel struck, the inrush of water would considerably impair her stability. The damage occasioned by the same shell striking above the waterline would not be nearly so great; from which it will easily be seen that for a battleship to have the greater part of her main belt below water may prove rather to be an advantage than otherwise, especially if, as is the case with modern American vessels, there is a good secondary protection above the main belt. Besides, a submerged belt may conceivably prove a defense against torpedo attack.—"Scientific American."

PRIVATE AND DOCKYARD SHIPBUILDING.

It is a self-evident proposition that our principal private shipbuilding yards are able to build warships quite as cheaply as the Government dockyards, and it is practically certain they are also in a position to construct ships at a lower cost than is incurred by the State shipyards. Everything is in favor of private enterprize in this respect, and if it had not been for the desire to exercise a check upon the amounts of tenders submitted by the firms, it is probable that the Government dockyards would not have been expanded to their present dimensions, or that they would be non-existent as State establishments. The yards would be available all the same, but they would be otherwise owned. The private yards, besides being advantageously situated for the provision of such raw materials as they do not themselves produce, construct the hulls and manufacture the plate and machinery, whereas the Government yards are dependent upon the purchase of the whole of the materials and equipment, which have to be transported over considerable distances to the dockyards at a large outlay in cost of carriage. The circumstance that foreign Powers place their orders largely with British firms bears eloquent testimony to the economy and efficiency with which the latter are accustomed to build vessels of every description, and it is probable that, with the exception of those nations which undertake construction on their own account, the whole of the requirements of the remainder of the world would be met by British yards if certain political and financial influences did not tend to divert a portion of the warship construction to other countries. Perhaps the case for British industry was never more concisely set forth than was done by Sir William H. White in the course of Cantor lectures delivered before the Society of Arts in 1906. The lecturer stated that "the construction of warships in this country costs less than that abroad; our resources in shipbuilding, engineering, armor and armament are so much greater than the corresponding resources in any foreign country, that the speed at which construction can be carried out is greater than that which can be

attained abroad." This statement, which was repeated in the following December in a comparison of British and foreign warship building capability that was published in the columns of the leading London newspaper, undoubtedly represents the position of affairs today, notwithstanding developments in the producing capacity of certain other countries.

The pronouncement made by the former Chief Constructor to the Admiralty forms somewhat of a contrast to the statement recently published by Lord Brassey, who, in the course of a letter on naval expenditure and administration, remarked that "if we have lost the advantage we once had in rate of building and cost of construction, we still possess unrivalled resources as shipbuilders." It is impossible to place upon the shoulders of private enterprize responsibility for any decline in the rate of building warships, as the lack of Government orders removes this matter entirely from the control of the shipyards; but the inference that the advantage in point of cost of construction has passed away from the British yards is certainly as unfortunate as it is incorrect. If we possess, as we undoubtedly do, unrivalled resources as shipbuilders, in what particular respect have we lost ground on the score of economical production? The private shipyards are still situated in the same positions, and their capacity for turning out warships has not only not been in any way impaired, but it never was on such a high plane of efficiency as at the present time. If the expenditure on construction is higher than it was a few years ago, the explanation is to be found in the increased cost of materials and higher wages. But as similar conditions prevail in other countries it is difficult to understand how it can be suggested that we have lost any advantage in the cost of construction. Any augmentation which has been experienced in the United Kingdom has been reproduced in other countries, whilst at the same time the latter, generally speaking, labor under the disadvantage of having to transport most of their raw materials and manufactures, exclusive, perhaps, of boilers and engines, over a distance that is considerably greater than in the case of the United Kingdom, excepting,

of course, the Royal dockyards. Lord Brassey is, however, on safer ground when he asserts that every ship we require for the Navy can be as well built by private firms as in the dockyards. The noble lord would, perhaps, not have been incorrect if he had remarked that the experience gained by the private yards, both on the construction of warships for the British Navy and for various foreign navies, tends to justify a claim that they are better able to deal with this class of work than the State dockyards.

The considerations already set forth have been suggested by a perusal of the Dockyard Expenses Accounts for the year 1906–7. At first sight it would appear from the general summary of aggregate expenditure as compared with estimates that whilst the direct charges for new construction undertaken in that year were slightly in excess of the estimates in the case of dockyard-built ships, the outlay on vessels constructed in private yards was considerably less than the original estimates. But on referring to the report of the Comptroller and Auditor-General we find a comparison of dockyard and contract results which purports to show that private enterprize is at a disadvantage as contrasted with the Government dockyards. For instance, a table indicates that the battleships *Dreadnought*, *Africa* and *Britannia* were built in the Royal dockyards at a total of £34,000 less than the original estimates, but the *Hibernia* involved an increased outlay of £16,000, thus leaving a balance of £18,000 in favor of the Government yards. On the other hand, the first-class cruisers *Achilles*, *Cochrane* and *Natal*, which were contract built, are returned as having resulted in a total expenditure of £157,000 beyond the amount of the original estimates. The report, in commenting upon the table, states that "the actual expenditure was less than the original estimate in the case of the dockyard-built ships, and greater in the case of those built by contract." This statement has, however, to be read in the light of the remarks made by the Admiralty in regard to the expenditure on each of the vessels. Thus the revised estimates for the three cruisers amounted to £141,000 more than the

original estimates, this reducing the excess of these vessels to merely £16,000. The Admiralty offers no explanation for the variations between the original estimates and the actual expenditure on the cruisers, and it is doubtless to be found in the alterations which are frequently made during the construction of the vessels. That this assumption is correct is fairly suggested by the observations made respecting the work actually done in 1906–7. During the year the outlay on the *Achilles* was £31,000 less than the estimates, and £6,000 less in the case of the *Natal*, whilst the expenditure on the *Cochrane* was £8,000 higher, owing to alterations and additions ordered during the building of the vessel. If explanations were also given for the total excess of the actual outlay over the original estimates or over the comparatively slight augmentations indicated by the revised estimates, it is probable that the suggestion as to cheaper construction in the dockyards would not have been made, seeing that the exceptional facilities enjoyed by the private shipyards, as previously mentioned, place them at an advantage over the Royal dockyards. —"The Engineer."

THE CRUISER PROBLEM.

The armored cruiser of the 1908–09 program is, it is presumed, of the *Inflexible* class, though rumors of a new departure have been plentiful. As in battleships, so in cruisers, multiplicity of types is not an advantage, and four ships of excellent but varying and non-homogeneous types are probably not equal to four of less individual power but homogeneous.

The ideal cruiser has been defined by Commander Hovgaard as a "battleship made extra large so as to secure increased speed without any sacrifices." The *Inflexible* type, of course, falls short of this, just as it also falls short of another very practical ideal for an armored cruiser—"a battleship that gives up some of its guns for speed." Such a cruiser, after losing some of its speed by damage in action,

could revert to the line as a battleship minus a gun or two. Sufficient attention was not, perhaps, however, directed to the fact that the *Inflexibles* fill a distinct ideal of another sort. They are "battleships which sacrifice some armor to speed." The point to be made in favor of this is as follows: The ships have sufficient speed to be able to avoid engagement whenever they please—unless, of course, cut off in narrow seas. But their gun power is such that even the finest battleships would hesitate to engage them, and on this account they could do a very great deal in the way of heading off a battle fleet which, were they "battleships with guns sacrificed to speed," they would hardly be able to do. A consideration of these two sides of the problem shows clearly enough that the Hovgaard ideal is the only really sound one for all eventualities, although the immense cost stands in the way of the construction of such vessels so far.

There is still a school of thought which insists that the vessel with moderate guns and moderate protection is the logical cruiser, even though paper demonstration of her utility may be difficult. There is one argument in connection with this school that is not often advanced, but which, none the less, has considerable potency, and that is, that however invincible any projected cruiser may be, it will never be long before something more recent comes along beside which she is relatively of small account.

The school referred to would postulate as its first requirement "numbers"—"numbers at all costs." It is, of course, patent that numerical superiority can only be secured by the sacrifice of invincibility to start with. Those who hold this view would, of course, argue that, given the necessary numbers, so long as the cruisers possess guns sufficiently powerful to damage an enemy, combination will give them all other necessary superiority upon occasions when it is required. This line of thought has few exponents now-a-days, but there is probably more forceful logic behind it than appears at a casual glance.

Without seeking to draw any particular moral from them,

these points may be mentioned in the hope that they may serve to concentrate attention upon the extremely delicate problem that is before constructors when armored cruisers are under consideration.—"The Engineer."

AMERICAN TURBINES FOR THE JAPANESE ARMORED CRUISER *IBUKI*.

Two large turbines now being built in the shops at the Fore River Shipbuilding Company should possess a special interest for American readers. They will form the motive power for the latest of the new Japanese armored cruisers, the *Ibuki*, a fine vessel of 14,600 tons displacement and 22 knots speed, which is now nearing completion at the yards at Kure, Japan. The significance of these engines lies in the fact that they are the first large marine turbines to be installed in a Japanese warship; and it is a distinct indorsement of the progress made in this country in the development of the turbine that such an astute people as the Japanese should have selected the Curtis type for the motive power of so valuable a ship. The *Ibuki* and her sister ship, *Kurama*, are identical vessels, with a length of 450 feet, a beam of 75½ feet, and a mean draught of 26 feet. We understand that the *Kurama* is being equipped with reciprocating engines, and, therefore, in these two vessels will be afforded an opportunity to test the respective efficiency of the two types of motor.

The later ships of the Japanese Navy, which are being built by the Japanese themselves, are distinguished, like the ships of our own Navy, by the unusually heavy batteries which they carry. Thus, the *Ibuki* mounts four 45-caliber 12-inch guns two in turrets; eight 45-caliber 8-inch guns in eight single turrets; and fourteen 4.7-inch guns, ten of them in a central battery and four in casemates, two at the bow and two at the stern. The ships are protected by a 7-inch belt and a 2-inch armor deck. The 12-inch-gun turrets have 7 inches protection, the 8-inch-gun turrets 6 inches pro-

tection and the 4.7-inch guns are mounted behind 5 inches of armor.

The motive power of the *Ibuki* consists of two turbines, which are designed to develop a normal horsepower of 24,000, sufficient to drive the *Ibuki* at 22 knots speed. They are intended, however, to develop a maximum overload horsepower of 27,000, which should suffice to give a speed of nearly 23 knots. The rotor is 144 inches in diameter. The casing has an outside diameter of 14 feet and a length over all of 17 feet. The weight of the two turbines together is 360 tons.

Each turbine consists of a cast-iron cylindrical casing divided by dished diaphragms into a series of separate compartments. In each compartment or "stage" there is a separate wheel, which carries on its periphery three rows of moving buckets (for reasons later described the first wheel has four rows). The wheels are all mounted on a hollow steel shaft carried by two bearings. Where the shaft passes through the diaphragms they are provided with bronze bushings having a small clearance, thus preventing appreciable steam leakage from one stage to the other. Where the shaft passes out through the ends of the casing it is provided with carbon stuffing boxes, which prevent steam leaking out at the ahead end, or air leaking in at the back end where a vacuum exists.

The stuffing boxes are supplied with steam in the space between the carbon packing, to prevent air leaking in and lowering the vacuum. They are also drained to the fourth-stage shell.

Cast-steel steam chests for ahead and astern running are attached to the front and back casing heads, and are flanged for the main steam pipes. The nozzles for each stage are bolted to the diaphragms, the diaphragms having steam-port openings cast in them to allow the steam to pass through to the nozzles.

Maneuvering is accomplished by means of two lever-operated balanced throttle valves, each taking steam from the

main steam pipe, and one delivering to the ahead steam chest and the other to the astern steam chest. There are seven ahead wheels and two reverse wheels. The reverse wheels are mounted in the after end of the casing, and under ordinary ahead running they are in a vacuum and, therefore, do not waste power by steam friction. They are similar to the ahead wheels, except that the blades are reversed. To reverse when going ahead, the ahead-throttle valve is shut and the reverse-throttle valve opened, which is easily and quickly accomplished by the operating levers of the two throttle valves.

Drain pipes are provided, connecting each stage with the next, so the condensed steam in any stage will pass to the next one of lower pressure, and there give up a part of its heat to do useful work. The exhaust chamber drains to the condenser and the discharge is assisted by a small steam ejector. A regular marine thrust bearing is attached to the forward end of the turbine shaft. In addition to taking the propeller thrust, this bearing also maintains the proper axial position of the rotor, so that the axial clearance of the blades is correct. This clearance is one-tenth of an inch on the first wheel and increases to one-quarter of an inch on the seventh wheel. The thrust is put at the forward end, so that any unequal expansion of the shaft and casing will be allowed for at the aft end, where the clearance is largest. This axial clearance is very ample to allow for all unequal heat expansion that may occur and any mechanical irregularities, and leave sufficient leeway for adjustment.

To allow for the increased volume of the steam as it expands in passing from stage to stage at lowering pressures, the lengths of the blades are increased and also the arc of the nozzles is increased, thus giving greater area of passage in each succeeding stage. Also, in any one stage, the blade lengths are increased in each succeeding row, because the velocity falls as the steam passes from row to row, although it is at practically constant pressure throughout the stage.

In order to keep the pressure in the shell as low as possible,

the pressure distribution is arranged so that one-fourth of the available energy of the steam is expended in the first stage and one-eighth in each of the other stages. This requires the first-stage nozzle to be of the expanding type, but all the other nozzles are of the parallel-flow type. Also, the first-stage wheel is provided with four rows of buckets instead of three, as on the other wheels, since the greater energy drop produces greater velocity of the steam jet from the nozzles, which requires more rows of buckets to properly absorb the energy at the bucket speed used. This arrangement makes all the ahead wheels except the first operate under eight-stage conditions. The principal advantages of the Curtis design of marine steam turbine are as follows: small number of blades; large clearance around blades; strong mechanical construction of blading; economy at reduced speed, without cruising turbines; interior of shell not subjected to full steam pressure; low revolutions for given horsepower; absence of dummy pistons and packing.

The small number, large clearance and strong construction of the blades make blade stripping practically impossible, and no case has occurred.

By the use of valves on the nozzle openings of the diaphragms, the proper steam-pressure distribution can be maintained at reduced steam flow, thus keeping up the economy at low speed of vessel, except, of course, for the unavoidable loss due to lower revolutions and dispensing with cruising turbines.

Full steam pressure comes on the steam chest only, which is a comparatively small steel casting. The greatest pressure in the turbine shell is less than one-third the working steam pressure. This permits high steam pressure to be used, and large turbine diameter in comparison to the power. It also reduces expansion difficulties.

The comparatively low revolutions permissible for a given power without sacrifice of economy or excessive weight allows the twin-screw arrangement to be used instead of three or four screws. Also, other conditions being the same, lower

revolutions will give a higher efficiency of the propeller. Low revolutions also permit the use of turbines in comparatively (for turbine vessels) low-speed vessels.

Absence of dummy pistons and their packing eliminates the leakage of high-pressure steam and makes the economy independent of any adjustments, so that the initial economy will be maintained continuously and will not be affected by any wear.—"Scientific American."

THE COMBINATION SYSTEM OF RECIPROCATING ENGINES AND STEAM TURBINES.

Extract from a paper read before the Institution of Naval Architects, April 9, 1908, by the Hon. C. A. PARSONS, C. B., F. R. S., D. Sc., M. A., and R. J. WALKER.

In the early years of steam-turbine design and development it became apparent that the turbine engine was capable of economically dealing with ratios of expansion far beyond the reach of any reciprocating engine, whose limitations in this respect had been experimentally determined by many investigations. In 1889 the first condensing turbine of about 100 horsepower was designed for an expansion ratio of 100 by volume, the expansion being effected in two turbines of the double parallel-flow type, the low-pressure turbine taking steam from the exhaust of the high-pressure at atmospheric pressure, and expanding it down to 1 pound absolute. The striking feature presented by this design was the very high estimated efficiency of this low-pressure portion. A separate low-pressure turbine was not, however, actually constructed till some years later.

In 1894 a patent was taken out for the "combination" of a reciprocating engine with a steam turbine, whose object was "to increase the power obtainable by the expansion of the steam beyond the limits possible with reciprocating engines." The previous treatment of the steam is, of course, immaterial, provided that its condition of pressure and wetness on reaching the engine are known. The first instance of a separate

turbine worked from the exhaust of other turbines was in the *Turbinia's* machinery in 1897; the pressure at entry of her low-pressure turbine was about 9 pounds absolute and the exhaust 1 pound absolute. The slip ratio of her three shafts showed that the low-pressure turbine developed about one-third of the total horsepower obtained from the steam at 160 pounds pressure, agreeing closely with calculations.

In the year 1902 the combination of reciprocating engines exhausting into turbines was first put to a practical test in His Majesty's destroyer *Velox*. In this vessel two small reciprocating engines were fitted for cruising purposes, of such power that, in combination with the main turbines, they would give an economical consumption at the speeds of 11 to 13 knots, the usual cruising speeds at the time the *Velox* was built. The arrangement of machinery consisted of one main high-pressure and one low-pressure turbine on each side of the vessel, each driving a separate shaft, or four shafts in all. A small reciprocating engine was coupled at the forward end of each of the low-pressure turbines. For speeds up to about 13 knots steam was admitted to the two reciprocating engines and expanded down to about atmospheric pressure; it then passed through the high-pressure, and thence through the low-pressure, turbines to the condenser. This combination gave excellent results at these cruising speeds. For speeds above 13 knots, however, the reciprocating engines had to be cut out and steam admitted to the turbines alone. With the advance of naval efficiency, the cruising speeds of war vessels have been increased, and in vessels subsequent to the *Velox* additional high-pressure turbines have been fitted, an arrangement which permits of good economy over a wide range of cruising speeds.

It may be said that perhaps the most important field for the combined system of machinery as applied to marine propulsion is for those installations where the designed full speed of the vessel falls below the range suitable for an all-turbine arrangement, the reciprocating engine working in the region of pressure drop where the conditions are best suited for it,

and the turbine utilizing that portion of the expansion diagram which the reciprocating engine is not able to utilize efficiently. It is generally well known that an all-turbine arrangement has not been advocated by us for ships where the designed speed falls below 15 or 16 knots, excepting in some special cases, such as yachts; and for vessels of moderate or slow speed the combination system of machinery appears to be eminently suitable.

In a good quadruple-reciprocating engine the steam is expanded down to the pressure of release, about 10 pounds absolute, and gains in economy as the vacuum is increased up to about 25 inches or 26 inches; whereas in a turbine it is possible to deal economically with very low-pressure steam, and to expand this low-pressure steam to a low absolute pressure corresponding to the highest vacuum obtainable in turbine practice.

In a combination system the most suitable initial pressure for the turbine, or the dividing line between the reciprocating engine and the turbine, will greatly depend upon the conditions of service of the particular vessel taken. The reciprocating engine, or engines, could be designed to exhaust at a pressure of between 8 pounds and 16 pounds absolute, or even at a slightly higher pressure, if necessary, to meet the conditions required. From an estimate of the theoretical efficiency under the various conditions of pressure, as set forth in the following table, it would appear, apart from any practical considerations, that there is nothing to choose between an initial pressure at the turbine of between 7 pounds and 15 pounds absolute, any pressure within this limit appearing to give the most economical result.

.....	Initial pressure turbine.	Reciprocating engine back pressure.	Theoretical B.T.U. per pound of steam.		
			R.E.	Turbine.	Total.
Assuming 200 pounds absolute at reciprocating engine to 28-inch vacuum at condenser.	15	16	178	142	320
	12½	13½	189	131	320
	7	8	218	100	318

In the case of a vessel which runs on service continually at or about her designed full speed, an initial pressure of about 7 pounds absolute at the turbine appears most suitable. In a vessel which does part of her running at the designed power and part at a considerably reduced power, it is desirable to design the turbines so that the initial pressure would not fall below 7 pounds absolute when running under the lower conditions of power.

.....	A Twin quadruple reciprocating engines.	B Three-cylinder triple-expansion twin reciprocating engines, with two low-pressure turbines in parallel.	C Four-cylinder triple-expansion twin reciprocating engines, with one low-pressure turbine.
Dimensions of reciprocating engines.	25, 36½, 51½, 75	27, 42, 66	26, 39, 46, 46
Revolutions of reciprocating engines.	55	48	42
Piston speed of reciprocating engines	84	85	100
Boiler pressure, pounds	770	680	700
Estimated pressure at H.P. receiver, pounds	213	213	213
Initial pressure turbines, absolute	200	200	200
Vacuum in condenser, inches	...	7	7
Steam consumption, main engines only, pounds per hour	26	28	28
I.H.P. reciprocating engines	95,000	95,000	95,000
Estimated equivalent I.H.P. of turbines	7,300	6,300	6,300
Total I.H.P.	...	2,000	2,000
Per cent. increase power	7,300	8,300	8,300
Estimated speed, knots	...	13.7	13.7
Steam consumption, pounds per total I.H.P. per hour main engines	15.5	16.2	16.2
Steaming weight of engines and boilers (reciprocating engines), tons	13	11.45	11.45
Weight of turbine installation, tons	...	1,430	1,455
Total steaming weight, tons	...	65	70
Revolution of turbines	1,560	1,495	1,525
	...	480	320

It may be of interest at this stage to consider the disposition of the turbines in combination with reciprocating engines on board ship. The arrangement of the turbine, or turbines, depends greatly whether the vessel is to be fitted with single

or twin-screw reciprocating engines. With a single reciprocating engine one turbine, two turbines in "series" or two turbines in "parallel" could be fitted, each turbine driving a separate shaft in addition to the reciprocator shaft. With twin-screw reciprocating engines an arrangement of one turbine in the center of the vessel, two turbines in "parallel," or two turbines in "series" could be adopted. The arrangement which seems to commend itself generally to shipowners and builders, where twin-screw reciprocating engines are fitted, is the arrangement with the turbine on the center shaft.

Owing to the rapid development of the turbine industry for high-speed work and the attention which was, in consequence, paid to this branch of the business generally, the development of the combination system fell more into the background than its merits and the wide scope of its application would seem to have deserved.

About two years ago, at the suggestion of Sir William White, designs were prepared of a combination system as applied to the intermediate type of liner of moderately large power and speed, and since that time numerous designs have been prepared for various types of vessels of speeds ranging from 13 to 16 knots.

By the courtesy of Messrs. Swan, Hunter and Wigham Richardson, who, for a considerable period, have taken much interest in this combination of machinery, the figures in the table are given of the comparative sizes of engines, power, etc., of the "combination" as compared with twin-quadruple engines, for a proposed steamer of 490 feet in length, 13,600 tons displacement, 7,200 indicated horsepower and 15½ knots speed.

In the combination proposals set forth in columns B and C in the above table it may be mentioned that in this particular inquiry the shipowners wished to have the advantage of the additional power and increase in speed of the vessel on the same coal consumption as for the twin-quadruple engines. In some instances an increase in speed might not be desired, in which case the boilers and engines could be reduced in

size by the estimated amount of saving in consumption, so that the total indicated horsepower of the combination did not exceed that required with twin-quadruple engines. This would considerably reduce the total weight of machinery, and also the bunker capacity for a given distance. This saving in the weight of the machinery and in the bunkers would enable the vessel to carry an equivalent addition in dead-weight cargo. Then, again, if we take the indicated horsepower of 8,300 for the combination, and assume that quadruple engines and boilers were required to give an equivalent power, the extra total weight of the machinery would be, roughly, 160 tons, in addition to an increase of about 12 per cent. in coal consumption for the same power.

In the arrangements for maneuvering in and out of port, suitable arrangements are made for changing the flow of steam of the low-pressure cylinder exhaust of the reciprocating engine from the turbine to the condenser. This can be done in two or three ways. One method is to have an ordinary change valve of the piston type, or ordinary double-beat spring-loaded valve actuated by links connected to the weigh shaft of the main engine, which would automatically change the flow of steam to the condenser when the engine was reversed. With this arrangement, when going ahead on one side of the ship, the steam from the reciprocating engine would flow through the turbine, but there does not appear to be any objection to this, even if we consider the twin-screw reciprocating arrangement with a single turbine on the center shaft. It might be rather an advantage, than otherwise, to allow the steam from the engine going ahead to pass through the turbine, as the center propeller revolving would accelerate the feed of water on the rudder and augment the turning power of the vessel.

Another method would be to work these valves independent of the main engines, actuated by an hydraulic engine or by an ordinary steam-driven reversing engine. With this arrangement the low-pressure turbine would be cut out altogether and the reciprocating engine would exhaust to the

condenser, whether going ahead or astern during maneuvering.

Enough has, perhaps, been said as to the general arrangement and estimated economy obtainable in the combined system, and now it may be of interest to refer to the general application of the system.

The development of the combination is already rapidly taking place on land, where the exhaust steam from non-condensing engines, especially the winding engines at collieries and rolling and mill engines, is being utilized in low-pressure condensing turbines. There are, at the present time, some twenty-four of these installations of the Parsons type delivered, working and under construction, ranging from 125 kilowatts to 1,250 kilowatts, representing a total brake horsepower of about 17,000. In most cases the exhaust steam is supplied to the low-pressure turbine at 15 pounds absolute pressure and a vacuum of 28 inches, and under such conditions about an equal amount of power can be obtained from the turbine as from the non-condensing reciprocating engine, thereby doubling the power of the plant without any further consumption of fuel. From several tests made with these exhaust turbines on land, a consumption of about 34 pounds per kilowatt-hour can be obtained in a 500-kilowatt machine, with an initial pressure of 15 pounds or 16 pounds absolute to 28-inch vacuum.

In regard to marine installations, the combination is being fitted to a large vessel at present under construction at the works of Messrs. Harland and Wolff for the Montreal trade of the Dominion Line. The arrangement of machinery in this vessel is substantially as described in column C of the Table previously referred to, viz: twin four-crank triple-expansion engines exhausting into one low-pressure turbine driving the center shaft.

Messrs. W. Denny & Brothers are also at present building a vessel for the New Zealand Shipping Company, which is being fitted with the combination system of twin triple-expansion engines and one low-pressure turbine. This vessel is an exact repeat of two other vessels Messrs. Denny have built for the same owners, except as regards type of engines.

In addition to the above, the Turbinia Works, in conjunction with Messrs. A. Stephen & Sons, of Glasgow, are fitting the combination system to the yacht *Emerald*. In this vessel, which was one of the first to be fitted with an all-turbine arrangement, it is intended to make some modifications to the existing arrangement of machinery by introducing a reciprocating engine on the center shaft in lieu of the high-pressure turbine at present in the vessel. This engine will be of the high-speed enclosed self-lubricating type, and is now being constructed by Messrs. J. S. White & Co. It is designed to exhaust into the two low-pressure turbines at about 15 pounds absolute pressure, the dimensions of the cylinders being 12½ inches, 19 inches and 30 inches, by 18-inch stroke, and revolutions about 350. It is expected that this vessel will be ready for trials in about four months' time.

TURBINES AND PROPELLERS.

It was almost inevitable that turbines should come in for most attention at this year's very successful session of the Institution of Naval Architects. During the past year there have been evolved data of a suggestive nature. The efficiency of the turbine is now placed beyond doubt; but, as is happily the case in all scientific pursuits, there are indicated directions in which progress is possible in subsidiary or auxiliary items in the complex problem of ship propulsion. Thus questions affecting steam generation, superheating, condensation and propeller design and the methods of arriving at satisfactory forms of hull have been brought more prominently to the front than formerly, as a consequence of the special requirements of the turbine; and on these topics papers were read and discussions took place, which we are fully reporting in the belief that the points raised must influence future marine practice. At the same there were interesting contributions on the construction of ships; but these, although in some respects original, can scarcely influence greatly the shipbuilding practice of the day.

The most conclusive paper, and the one which was awaited with greatest interest, was that on the *Lusitania* turbine performances. It quite met expectation, and it nailed many misstatements to the counter, so that its author, Mr. Thomas Bell, of Messrs. John Brown & Co., Limited, is to be congratulated. In the first place, it proved that the turbines of this ship, as well as of her consort, the *Mauretania*, have a high efficiency. From the data given we have worked out the thermo-dynamic efficiency as 62.6 per cent. at 68,850 horsepower, which is very favorable, and compares with 61.3 per cent. at 23,000 horsepower in the *Dreadnought*. The coal consumption for all purposes on the *Lusitania's* best Atlantic trip was under 1.5 pounds per horsepower per hour, when running at full speed. Consistent with all experience, the coal consumption steadily increases with decreased speed, the rate for 15 knots being 2½ pounds; but the Atlantic liner always runs at full speed, so that we have ideal conditions for the application of the turbine. A pertinent question by Admiral Henderson enabled Mr. Bell to state definitely that the total coal consumption was quite in accordance with expectations. The bunker capacity is 6,300 tons, and the vessel can steam at 25 knots across the Atlantic and have still enough coal to carry her 500 nautical miles farther. At full speed her radius of action is thus about 3,400 nautical miles. The total steam consumption of all the machinery is 14.46 pounds per horsepower hour, but of the steam turbines only 12.77 pounds, which latter figure compares with 13.4 pounds in the *Dreadnought* and 13.6 pounds in the *Amethyst*. But on these Atlantic liners, as Mr. Bell pointed out, the demand for hot water and for steam for auxiliaries is abnormal. These results are all very satisfactory.

The propulsive efficiency works out to about 50 per cent. at full speed. This is about the same as the *Dreadnought*, but is rather less than in the case of twin-screw reciprocating-engine propelled ships. As we have time and again pointed out, the important question of the day has reference to the propeller. As one speaker remarked, it would be all right if one could design turbine or propeller without reference to the

other. The higher thermo-dynamic efficiency of the turbine justifies a forfeiture of some part of the efficiency of the propeller. In the turbine a high rotational speed is aimed at, as it is desirable that the blade speed should have a high ratio to steam speed. In the propeller the peripheral speed should be minimized and the thrust moderate, otherwise there is possibility of loss. A compromise between these conflicting elements is aimed at.

The further study of the propeller problem is being followed with characteristic care. So far the results in the case of the two Cunard liners are good, and we are sure that, as Mr. Andrew Laing put it, when the ships, staff and stokers settle down both ships will exceed their 48-hours' trial performance. Meanwhile the views put forward by Dr. Froude and Mr. Parsons as to 20 to 22 per cent. being a preferable ratio of slip than 15 to 17 per cent., and as to the relative efficiency of different forms of blades, are important.

The question raised in connection with the trials of the turbine-driven destroyers of the *Tartar*, or so-called "Tribal," class is quite different, but here also the turbine has proved very efficient. Although not brought out at the meeting, we believe the steam consumption was about 14 pounds per horse-power hour in this case also, as compared with nearly 20 pounds in vessels of the same type having reciprocating engines. The speed problem here was associated with the depth of water over the ground traversed by the boats. This point was, unfortunately, complicated by others which are not germane to the scientific question involved. No one disputes the fact that under Admiralty conditions, and on a measured mile approved by the Admiralty, the *Tartar*, *Mohawk* and other vessels have, while in a trim according with specified requirements, achieved speeds ranging up to 35.36 knots in the case of the *Tartar*. That was the speed registered by the Admiralty staff on board. We speak thus decidedly, as there may be misunderstanding as a result of the discussion at Wednesday's meeting of the Institution, and reported in last week's issue. This explanation, too, is important owing to the tendency for British writers and speakers to assist foreign critics

in decrying British results. We manufacture largely for foreign owners, and it is important, from the commercial point of view, that there should be no possibility of misunderstanding. This is altogether apart from the utilizing of an institution which is now almost international in its membership and in its proceedings for the advancement of British trade interests. French, Italian and other Continental writers have been putting forward the need for scrupulous accuracy in the discussion of results so as not to affect foreign clients to the disadvantage of national trade, and this necessity should not be neglected in this country. The scientific point regarding the speed of the destoyers must therefore be dissociated from the commercial question.

The subject of the influence of depth of water on speed is one of great importance. The 25½-knot destroyers of the "River" class had difficulty in getting the designed speed except in deep water, and the Skelmorlie mile on the Clyde was preferred by some firms for its 40 fathoms of water to the Maplin Sands mile with its 10 fathoms. As has before been shown by Mr. Yarrow, this relation of depth of water to speed and form is a most difficult one, and in view of the disparity in results got with the destroyers of the 33-knot class on the measured mile at Skelmorlie and those tried on the Maplin Sands, the Admiralty have very advisedly decided to have a series of trials with the *Cossack*—the first of the new destroyers of the class to be completed—on the principal measured miles in the country. The conditions will be as nearly as possible identical, the only variant being depth of water. These data will be a most useful supplement to the splendid results already recorded for this type of vessel.

The combination of reciprocating engines and low-pressure turbines, the latter to take the exhaust from the former, has been adopted on land stations, particularly where the load on the piston engine is intermittent; and it is gratifying to note that three steamers are now to be fitted with a combination system. This, as Mr. Thomas Bell pointed out, is a development corresponding with triple and quadruple-compounding, as it similarly improves the temperature range. The question

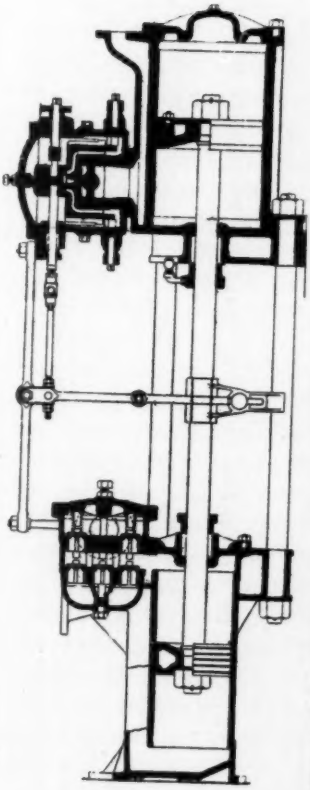
at issue seems to be whether the engine to be used should be compound or triple-compound. There are even those who advocate simple engines; but the range of expansion from 200 pounds or 210 pounds boiler pressure might be too great for one cylinder. There are other problems associated with difference in shaft speeds for the two types of machinery, with the exclusion of oil from the turbines.—"Engineering," April 17, 1908.

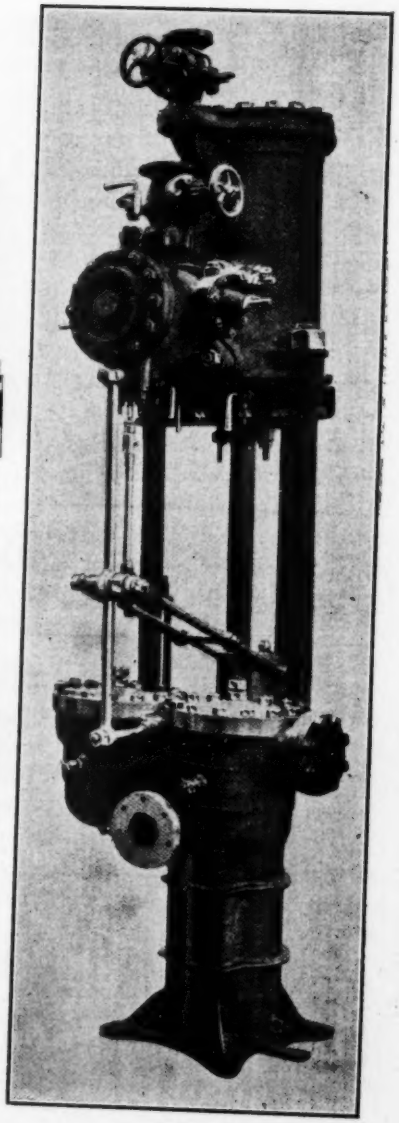
FEED PUMPS FOR THE ITALIAN NAVY.

A complete set of main and auxiliary feed pumps for the Italian cruiser *San Giorgio* have recently been provided by Messrs. Henry Watson and Sons, of High Bridge Works, Newcastle-on-Tyne. The pumps, which are shown in the engravings on page 467, are of the single-cylinder direct-acting Admiralty type, and have 10¾-inch barrels by 24-inch stroke. They are fitted with balanced valves and special self-adjusting buckets. The duty of each pump when drawing through a suction pipe of 160 feet length with a lift of 7 feet was specified as 50 tons per hour, against 255 pounds boiler pressure at fourteen double strokes per minute and exhausting against 10 pounds back pressure. The actual results obtained on a series of exhaustive tests run under working conditions—in the presence of Major Girola, of the Italian Admiralty—were, we understand, considerably in excess of the specified duty, and a high pump efficiency was obtained at both low and high speeds. The steam consumption was not specified, but although the trials were run before the cylinders and pipes were lagged, the steam used was taken to an auxiliary condenser and measured. The results obtained at the trials mentioned are given in the table below.

Revolutions per minute.	▾	6	8	10	12½	14½	15	16	17
Gauge pressure at cylinder	148	152	155	170	172	173	175	176	178
in discharge	255	255	255	255	255	255	255	255	255
Tons pumped per hour	14.92	23.0	30.75	39.5	50.0	58.5	59.6	63.25	67.5
Pump efficiency per cent	92.75	95.0	95.5	98.0	99.25	98.2	98.6	98.0	98.5
Steam horsepower	13.0	19.55	26.2	29.5	39.2	45.0	46.5	50.0	54.0
Water horsepower	11.0	16.6	23.1	28.25	35.2	41.5	42.5	45.75	48.5
Water h.p. / Steam h.p. per cent	84.5	85.0	88.4	96.0	90.0	92.3	91.5	91.2	90.0
Steam used per I.H.P. per hour, lbs	78.0	75.0	67.8	69.5	62.5	57.3	56.25	54.0	51.4

"The Engineer."





RELATIVE WEIGHTS AND SPACES OCCUPIED BY MACHINERY IN TYPICAL VESSELS.

Name of Vessel.	*Deutschland.*	*Celtic.*	*Glenlyon.*	H.M.S. *Defence.*	H.M.S. *Temeraire*	*Duke of Cornwall.*	S.Y. *Tuscarora.*
Type of vessel	Atlantic liner	Intermediate liner	General cargo	1st-class cruiser	1st-class battleship	Cross-chan'l st'mr	Pleasure yacht
Builders	Vulcan Co.	Harland & Wolff	Scotts', Greenock	engines by Scotts'	engines by Hawthorne, Leslie	Vickers	Scotts', Greenock
Owners	Hamburg-Americn.	White Star	Gardiner & Co.	British Admiralty	British Admiralty	L. & N.-W. R. Co.	W. Jennings
L. by B. by D.(mld.) ft. and ins.	662-9 by 67-0 by 44-0	680-0 by 75-4½ by 48-4½	377-0 by 49-6 by 28-9	490-0 by 74-6	490-0 by 82-0	315-0 by 37-0 by 17-6	181-0 by 26-0 by 14-5
Displacement, tons	23,620	33,550	9,782	14,000	18,600	2,830	790
Gross tonnage	16,502	20,880	4,149	...	...	1,540	541
No. of propellers	2	2	1	2	4	2	1
Type of engines	6-cyl. quadruple	4-cyl. quadruple	3-cyl. triple	4-cyl. triple	Parsons' turbines	4-cyl. triple	3-cyl. triple
No. and type of boilers	12 D.E. and 14 S.E.	8 D.E.	2 S.E. cylindrical	24 Yarrow W.T.	18 Yarrow	4 S.E. cylindrical	1 S.E. cylindrical
Working pressure, pounds	220	210	180	250 at engines	170 at engines	180	200
System of draft	Howden's forced	assisted	Howden's forced	closed stokehold	closed stokehold	closed stokehold	closed ashpit
Speed, in knots	23.51	16.0	10.75	23.0	21.0	19.75	13.15
I.H.P. on full-power trial	85,000	13,000	2,400	27,000	23,000 (shaft H.P.)	5,530	1,100
Superficial area per I.H.P.:							
Engine room, square feet	0.139	...	0.428	0.109	0.208	0.165	0.27
Boiler room, square feet	0.286	...	0.31	0.226	0.23	0.24	0.333
Total, square feet	0.425	0.96	0.738	0.335	0.438	0.405	0.60
Total weight of machinery, "Steam up," tons	5,670	2,475	474	2,368	1,890	612	132
Weight as per cent. of displacement	24.0	8.87	4.85	16.2	10.15	21.6	16.7
I.H.P. per ton machinery	6.35	4.37	5.06	11.75	12.17	9.02	8.35
I.H.P. per gross registered ton	2.12	0.62	0.58	...	...	3.58	2.04

RELATIVE COSTS OF DIFFERENT TYPES OF MARINE PROPELLING MACHINERY.

Description.	Rate per I.H.P. (full-power trial).		Rate per ton of Finished weight—"Steam up."	
	£	£	£	£
Merchant vessels, with reciprocating engines and cylindrical boilers:				
Large ocean liners	6.5	to 7.0	36.5	
Intermediate liners	5.5	6.5	34.0	
Cargo tramps	5.0	5.5	23.0	to 26.5
Cross-channel steamers	5.5		48.0	52.0
Pleasure yachts	7.5		55.0	
Naval vessels, with reciprocating engines and water-tube boilers:				
1st-class cruisers	10.6	11.25	120	
3d-class cruisers	6.5		105	
Destroyers	5.5	6.5	200	225
Battleships, with turbines and Yarrow boilers, per shaft H.P.	11.13	11.35	137	140

THE WEATHERING OF COAL.

By S. W. PARR, Professor of Applied Chemistry, and N. D. HAMILTON, Fellow in Chemistry, University of Illinois. (In connection with the Illinois State Geological Survey.)

The weathering of coal is a subject of perennial interest. Moreover, its importance is not likely to grow less in view of the trend of modern industrial conditions. Almost every circumstance attending the production and use of coal calls for flexibility in the current supply. The seasonal changes in greater temperature, the fluctuating demands for freightage, the periodical disturbances in the labor supply, all argue for the possibility of carrying at certain periods a reserve of fuel to guard against suffering or complete paralysis of industry.

It is not surprising, therefore, to learn of the increasing number of storage plants where coal may be placed in large quantities to supply the needs of great industries which would suffer if from any cause or combination of circumstances a coal famine should ensue. An example of this is the plant of the Philadelphia and Reading Coal and Iron Company at Abrams, Pennsylvania. At this plant arrangements are made for eight piles of coal, each containing 60,000 tons, piled on the ground in the open and equipped with modern facilities for dumping and reloading. The storage plant also of the New York Edison Company at Shadyside, New Jersey, where 150,000 tons of coal are stored in three piles on a bed of cinders in the open, and that of the Lehigh Railroad at Wyoming, New York, with a capacity of 100,000 tons, are but a few of the instances where our industries are resorting to outdoor storage for reserve coal supplies. This method of storing is not only the practice where large quantities of coal are to be taken care of, but there are very few power and heating plants and fuel-using industries that do not find it necessary to pile more or less coal on the ground, at least temporarily, until room can be made for it in the coal shed or boiler house. The practice in vogue in the coal fields, among coal dealers and all consumers of comparatively small quantities varies greatly. In general, however, it may be said that the coal is

either stored in covered iron or wooden bins with slanting bottoms to facilitate its removal, or in ordinary covered bins with earth, cinder or wooden floors, from which it is removed with the scoop. In power and heating plants the placing of the coal bins depends upon the position of the boilers and the method used for firing and transportation of the fuel to the building. The United States Navy, which uses about 250,000 tons of coal yearly, has been equipped with large storing facilities, each compartment in the station at the New York Navy Yards having a capacity of 525 gross tons, with floors of portland cement, roof of iron and side walls of portland cement, sand and anthracite cinders. On board vessels coal is stored in whatever room happens to be available.

Aside from these prevalent methods of caring for coal reserves, the practice of storing coal under water is coming into prominence, but the working out of this plan cannot be said to have gone further than the experimental stage. The English Admiralty has been experimenting with submerged coal, and the Western Electric Company of Chicago has recently built two bins of 4,000 and 10,000 tons respectively below the ground level. The plan is to dump the coal into the bins directly from the car and flood it with water until needed for use, when a crane fitted with grab buckets will lift it to the car again.

As one reviews the literature of the subject it is strikingly evident that well authenticated facts and data are very meager, with much disagreement among those who have presumed to possess knowledge in the matter. There is a general belief that coal does deteriorate, but under what conditions, to what extent, and according to what principles, are certainly open questions at the present time. The following resumé of the statements by various writers will be of advantage in gaining a present knowledge of the situation. There are included also, references which deal with the spontaneous ignition of coal, on account of the close relationship of that topic to the one in hand.

HISTORICAL REVIEW.

After careful experiments, Dr. Richter, in 1868*, concluded that the weathering of coal is due to the absorption of oxygen, a part of which goes to the oxidation of carbon and hydrogen in the coal, and part is taken into the composition of the coal itself; that if the heap becomes warm, either through this process or through any other cause, the action is accelerated, but then falls off and becomes so slow that the changes effected within a year are difficult to estimate; that moisture as such has no direct influence upon the process, apart from the presence of pyrites or from the coal crumbling down more rapidly when wet than when dry, and, therefore, more rapidly heating up. At a later date, he concluded that large coal was less affected than small, not because it had less surface, but because small coal was a more active absorbent of oxygen, and therefore, became more rapidly heated; that airways in heaps would have to be very numerous in order to prevent any rise in temperature.

Haedicke, in 1880†, while assigning to pyrites the leading part in spontaneous combustion, agrees that this hypothesis does not hold good unless the temperature is allowed to rise sufficiently.

Professor Fischer, of Gottingen, as a result of research work prior to 1901†, concludes that storage depreciation and spontaneous ignition are phenomena of oxidation; the part which is played by iron sulphide has been disputed, but the variances that have given rise to the uncertainty are due to the differences between the different sulphides of iron present in coal. Marcasite, for example, he says, is much more weatherable than ordinary pyrites. Actual wetting is much more promotive of oxidation of the iron sulphide than heating in dry or even moist air. He also finds that many coals contain sulphur in the form of unsaturated organic compounds. He finds that those coals which rapidly absorb bromine are those

* "Proc. Ger. Gas Association," 1900.
† "The Gas World," April 13, 1901.

which are most liable to rapid oxidation and spontaneous ignition, and as a practical test he recommends shaking a gram of the finely-ground coal with 20 cc. of a half normal solution of bromine for five minutes. Then if the smell of bromine has not disappeared, the coal may safely be put in store; if the odor has gone, the coal should be used up as soon as possible. If the oxygen is absorbed by the unsaturated organic compounds, the coal gains weight, but if absorbed by the carbon and hydrogen, this absorption causes a loss in weight due to the carbon-dioxide and water given off. Whether a coal gains weight is, therefore, dependent upon the composition of the coal. Covering wet slack coal with other coal is apt to produce spontaneous ignition; the danger here appears to arise from the sulphide of iron rather than from the organic compounds. Professor Fischer regards ventilation of the coal heap with suspicion, not because the idea is in itself wrong, but because it is not practicable to ventilate the whole heap sufficiently. He says the coal should be stored dry and kept dry under cover and in layers not too deep.

Durand, 1863*, explains the spontaneous ignition of coal in the pit by the presence of pyrites, which, becoming heated, gives rise to combustion. Payol maintains that the main cause of spontaneous ignition is the absorption of oxygen accelerated by fine division and heat.

Jackson, 1905†, says it is well known that coal on exposure to the weather does lose some of its volatile constituents even under ordinary conditions.

In a paper read before the German Gas Association in 1900‡, Herr Sohren said that it is no longer possible, for many reasons, to operate gas works with a supply of coal renewed from month to month; and that all questions affecting storage have, therefore, a continuously increasing importance. Undoubtedly there is a greater or less depreciation in quality of

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*"Journal American Chemical Society," Dec., 1900, and July, 1904.
†"Engineering and Mining Journal," July 14, 1906.
‡"Gas World," April 13, 1901.

coal kept in store; and the causes of this have attracted a great deal of attention, though, on the whole, it is surprising to find to how great an extent the study of the chemistry of coal has been neglected. Questions of this nature first assumed importance in connection with the spontaneous ignition of coal in ships; in 1874 he declares that out of a list of 4,485 coal-laden ships, no fewer than 60 went on fire.

Lieutenant Commander J. R. Edwards, of the United States Navy, 1901*, said that experience has taught the dealers at Trinity Building, New York, that every time coal is handled there is a depreciation of five per cent. in value due to the loss in weight by the breaking up of the coal and the volatilization of the hydrocarbons. It is a fact that the best coal does not disintegrate and powder so quickly as the poorer quality. According to his theory, the hydrocarbons make it less friable.

Groves and Thorp† state that gases occluded in the crevices or cavities of coal escape during mining and continue to do so after storing, and that disastrous explosions on vessels carrying coal cargoes have resulted. An analysis of these exuded gases reveals their inflammable nature and suggests the probable action of the air on coal which is exposed to it for any length of time. This latter action is termed "weathering," and consists mainly in the combination of the carbon and hydrogen of the coal with the oxygen of the air, carbonic acid and water resulting. Pyrites, if present, is also oxidized, and when present in large quantities causes the coal to disintegrate and oftentimes to be nearly useless. Calorific value is diminished by this exposure to the air, and in some cases there is claimed to be 50 per cent. loss. Oxidation may proceed so far that elevation in temperature occurs and spontaneous combustion results. Oxidation of pyrites, especially in the presence of moisture, greatly adds to the danger. To avoid the small coal, the packing of coal in lumps in vessels is proposed, but the movement of the ship would break up the coal and only

* "American Society of Naval Engineers," Feb., 1901.
† "Chemical Technology," Vol. 1, page 82-83.

delay the action. Sealing up the coal hermetically has also been suggested, but this would be impossible.

T. Rowan suggests the heating of coal to drive off the moisture before storing on board. The plan is a poor one on account of the cost and the oxidation which the heating would promote.

A. D. Parker, General Auditor, Colorado Southern Railroad, 1902*, states that the loss in transporting coal has never been definitely determined. It consists of shrinkage, droppings, stealing, etc. Evaporation or shrinkage is inevitable. It is greater with softer coals and diminishes with density. Where coal is placed in storage, shrinkage becomes a very large item.

Mr. Stelkins, in his report before the International Navigation Congress, 1902†, states that the tendency towards spontaneous ignition increases with the height to which coals are heaped. Stacks should not be made higher than five meters. Warm rains during and after stacking and strong compression by dumping coals from a great height all add to the danger of ignition. According to past experiences, gas-flaming pit-mouth coals ignite most readily, fat pit-mouth slack, lean slack and nut less readily, and lump coals only very seldom. When the amount of slack increases, and the amount of stony material increases, the height to which it is safe to store coal decreases. Mr. Zorner, in this same convention, claimed that lightering coal renders it more liable to physical and chemical attacks and more difficult to use as fuel. Rischowske ascertained a loss of three per cent. in calorific power of fresh slack coal after a storage of four months.

"Engineering News," July 21, 1904, notes that in the New York Navy Yard space is not an item, but spontaneous combustion is an important one, hence the coal depth is limited to 18 to 25 feet, and the walls surrounding the bins are fireproof. In each bin which contains 525 tons of coal are placed two four-inch pipes, each containing thermostats elec-

* "Railway Engineering News," May 3, 1902.
† "American Society of Naval Engineers," Feb., 1901.

trically connected to an annunciator. These thermostats containing tubes are arranged so as to be moved completely through the coal. A method of removing coal from the bottom of the bins is provided, and this may be done and the portion removed and redistributed over the top to prevent fire.

F. M. Griswold, of the Home Insurance Company, 1904*, says that spontaneous ignition is more marked in free-burning or so-called "high-steaming coals" including "gas coal." These coals usually contain a large per cent. of volatile constituents with a modicum of oxygen, and the tendency to ignition is greater when lignite or sulphur in any form, and especially when iron pyrites is present. Dirty or mine-run coals, wherein fine particles sift to the bottom and are compressed, are dangerous. He claims that no satisfactory explanation of spontaneous ignition of bituminous coal has been made. The best authorities say it is due to chemical changes in the substance of the coal resulting from the absorptive powers of carbon increasing with the rise of temperature. Rise in temperature may be due to the chemical action in the form of the slow oxidation or to mechanical force or pressure and these conditions may be stimulated by pyrite or moisture. Some claim that over 2½ per cent. of sulphur in the form of pyrites is dangerous. Various tests have been proposed to determine the liability of a coal to heat, such as determining the gain in weight of a sample at 250 degrees Fahrenheit and also by noting the absorption of bromine, but these are not valuable, as it is difficult to tell how much oxygen the coal has already absorbed. He recommends that no wood be used in the construction of bins, that all iron work be covered with concrete, that there should be no steam pipes or flues in bins, the coal should not be above a depth of twelve feet, bins should be roofed, permanent pipes should be provided, if possible, containing thermostats through the bin, and when 140 degrees Fahrenheit is reached something should be done to stop rise in temperature.

Professor Vivian B. Lewis, Royal Naval College, 1906†,

* "Engineering News" 27, 1902, July 21, 1904, Aug. 18, 1904, and Nov. 10, 1904.

† "Engineering and Mining Journal," July 14, 1906.

is authority for saying that increase of mass leads to spontaneous combustion. Substances, especially those of vegetable origin, undergo slow oxidation at temperatures below ignition point. A certain increment of temperature is generally needed to start slow combustion, but when once the required rise takes place, the operation commences and the ignition point is reached. Initial increase may be brought about in several ways: first, by physical action, as in the absorption of a large volume of gas and its compression within the pores of the substance; second, by a rise in atmospheric temperature; third, by a direct chemical reaction taking place at ordinary temperature and by the action of ferments on moist organic matter. To the first class belongs the spontaneous ignition of a mass of powdered charcoal or lamp black. Coal may be considered as consisting of carbon, hydro-carbons and inorganic constituents. Among the latter is iron pyrites. If piled in heaps and exposed to air and moisture, it rapidly heats and often inflames, owing to the oxidizing action of the air and moisture upon the sulphur. Many think this is the cause of spontaneous ignition. Careful study of phenomena occurring during the heating of coal leads to the conviction that pyrites plays but a subsidiary part, and that it is really the absorption of oxygen by the freshly-won coal and the activity of the condensed gas in contact with the hydrocarbons of the coal that are the active factors in causing ignition. In the coal seam coal pores are filled with methane or methane and carbon dioxide. When coal is brought to the surface it exudes these gases and absorbs oxygen from the air. As long as the pieces are fairly large no heat is perceptible, but as coal becomes broken up the surface increases and the absorption of oxygen is increased. Mere absorption of oxygen is insufficient to bring about serious consequences unless there is an initial rise in temperature. Hence, spontaneous ignition is found to occur when cargoes go through the tropics and when coal is stored close to boilers, steam pipes, fire boxes, etc. Water aids the action of the occluded oxygen, and hence rain, when coal is being loaded, causes danger. Ventilation of

coal on land may aid in preventing ignition, but this is hard to obtain on shipboard. Steam and water have failed to quench fires successfully. Sulphur dioxide and carbon dioxide will extinguish the fires, but not cool the coal and prevent another fire. He suggests that liquid carbon dioxide be placed in vessels whose nozzles are made of an alloy of lead, tin, bismuth and cadmium melting at 93 degrees centigrade and that these vessels be placed in the coal bins. When the melting point of the alloy is reached the carbon dioxide will quench the fire, cool the coal, be absorbed by the coal and prevent any further occlusion of oxygen.

A. E. Dixon, 1906*, says that bituminous and semi-bituminous coals are losing constantly in heating value. Gas is being liberated and the loss is greater in a warm climate and in warm weather. Bituminous coals undergo a slacking process, the lumps shrink and the percentage of dust increases. In winter the contained moisture freezes and breaks up lump coal. Spontaneous ignition occurs with bituminous, friable coal, and particularly with those grades containing brasses or iron pyrites, and when the coal is damp the trouble is augmented. The cause is probably due to the absorption of oxygen by carbonaceous material, just as is the case with oily cotton waste.

H. R. King, 1905†, claims that the carefully-executed tests in Europe show that 30 per cent. of the fuel value of coal is lost in six weeks when coal is stored out of doors.

The Naval and Military Record of England‡ gives an instance of where the British ship *Spartiate* required 3,000 tons of coal stored in England in running to China and 4,400 tons of practically the same grade of coal that had been stored in China for the return trip.

Lord Charles Beresford, 1903§, stated that in his experience a vessel would have to consume more than twice the normal amount of coal per indicated horsepower if the coal had been kept too long in store.

* "Engineering Magazine," September, 1906.
† "Journal Western Society of Eng.," Aug., 1906.
‡ "Engineer," July 24, 1903.
§ "Practical Engineer," Oct. 2, 1903.

Churchyard, locomotive engineer of the Great Western Railway, England, 1902*, stated that judging from his personal experience and observation, the loss of stacked coal in steam-raising power is about 10 per cent.

"Mines and Minerals," 1901†, says that for many years there has been in vogue in New South Wales a custom of taking certain percentages from the gross weight of coal cargoes, giving bills for the net quantity only. The idea was to allow for the wastage which it was thought took place in various ways between the time of weighing at port and delivery. The practice has been to deduct two per cent. from the gross weight of foreign exportations and one per cent. from that intended for intercolonial markets. On account of the dissatisfaction with this method, on January 1, 1901, the deduction on foreign cargoes was reduced to one per cent. and no allowance is now made on intercolonial cargoes.

The "Journal of the Society of Chemical Industry," 1894‡, says that various kinds of coal were exposed freely to the air, immersed for twelve months in water, both running and stagnant, and changes produced in their composition and heat of combustion determined. The three kinds of coal used were, (1) from Frankenholz mine, Bavaria; (2) from Drocourt; (3) from Arsean, Prele. These coals were broken and passed through 10 mm. mesh, but not 3 mm. mesh. Measurements show that exposure to the air or immersion in water for the time indicated produces changes in the composition and heat of combustion which are so small as to be neglected for practical purposes.

John Macaulay, General Manager of the Alexandra Docks and Railway, Newport, Monmouthshire, 1903*, estimates that in case of coal stacked by the Mersey Railway the loss was between 10 and 12 per cent., and, if kept over a year, the greatest loss is in the first twelve months. In hot climates the loss is greater. Mr. Macaulay says that the mud men

* "Practical Engineer," Oct. 2, 1903.
† "Mines and Minerals," 1901, p. 6.
‡ "Jour. Soc. Chem. Ind.," 1894, p. 1182.

along the Usk River gathered parts of submerged cargoes and found that the coal gave a hotter fire than did fresh coal. In North Pembrokeshire they refloated a vessel which had been sunken for two years and found that the coal was the best they had ever used. Mr. Macaulay's own experiments include the placing of a sample of the best Monmouthshire coal under sea water for two months and comparing the calorific value before and after immersion. He found the loss in heating value was less than one per cent. In his further experiments he made a practical test of fresh coal and coals known to have been submerged various lengthy periods of time, by using them in a locomotive hauling a known load a certain distance under similar conditions. His first sample was the best Monmouthshire coal procurable, the second sample had been under water three years, the third had been submerged ten years, the fourth had been recovered by mud men outside of the mouth of the River Usk. This latter was driftage from the wrecks in the Bristol Channel, and had probably been under water considerably longer than ten years; this sample he called "river coal." The order of value in steam-raising and actual working results, in which the coals came out in tests, was: (1) the river coal; (2) coal that had been under water ten years; (3) fresh coal; (4) coal that had been under water three years. Comparing values with the fresh or test coal, the river coal was 4 per cent. better, and that which had been under water ten years 1.8 per cent. better. That which had been under water three years had lost 1.6 per cent. of working power. The high value of the older river coal, he says, may probably be accounted for by the fact that in traveling through the mud and sand that gave it its rounded form the harder and better kernels, as it were, had been preserved, and the looser-textured, less valuable outside portions were worn away. As a result of his experiments Mr. Macaulay concludes that steam coal loses very little of its power by submersion under water for the length of time that it would reasonably be kept in naval store, and that as it is so important to naval vessels to gain the benefit

of their full working power, and so much of this is due to the coal, the subaqueous storage of coal is advisable in place of the present methods of storing with access to air, by which so high a percentage of working power is lost.

SUMMATION OF OPINIONS.

Judging from these opinions of practical engineers and scientists, the present methods of coal storage without doubt often result in much loss from fires of spontaneous origin and more or less loss by a deterioration in fuel value of the coal itself. The leading factors entering into the cause of these losses have been pointed out as being: (1) the kind of coal as to its volatile combustible content; (2) the presence of occluded inflammable gases in the coal both before and after mining; (3) the presence of pyrites or other sulphur compounds; (4) the size of the coal; (5) the presence of moisture; (6) the temperature; and (7) the accessibility of oxygen to the coal.

From the evidence at hand there seems to be very little doubt that the coals of the lignitic, bituminous and semi-bituminous character with their relatively high amounts of volatile combustible matter have a much greater tendency to weather than the anthracites where the volatile matter is low. There is considerable evidence that methane and other inflammable gases formed during the decomposition of vegetable matter which produces the coal are contained in the crevices of the coal as it lies in the earth, and are liberated both during and after mining. This exudation of inflammable gaseous matter may be a prime element in mine explosions, and its continuance after storage may be a large factor in the deterioration processes.

Opinions differ as to just what part sulphur compounds, the most important of which is pyrites, play in the deterioration of coal. Some assign the leading part in cases of spontaneous ignition to pyrites, while others think that its action in this connection is of only minor importance, and that absorbed oxygen has most to do with this phenomenon. Observations on

the effect of the air upon pyrites, however, seem to have pretty generally established the notion that pyritic oxidation tends to raise the temperature of the coal as well as to increase the tendency of the coal to break up, and that this oxidizing action is quite appreciably increased by the presence of moisture.

That slack is much more liable to spontaneous ignition and the deteriorating influence of weathering agents seems to be the general opinion. Having more surface the finer particles absorb oxygen much more rapidly, and this rapidity of absorption causes an increase in temperature which in turn produces better conditions for absorption and chemical action between the carbon, hydrogen and pyrites of the coal and the absorbed oxygen. It would seem that the finer coal would hold the moisture longer, resulting in a greater use being made of its catalytic qualities.

It is thought by some authorities that the only part moisture plays in the deterioration of coal is to materially assist the pyritic oxidation, or by alternate freezing and thawing in the crevices of the coal to expose more surface to weathering agents. There are many, however, who believe that, aside from increasing the oxidation of pyrites, water has to do with other chemical activities which result in the decomposition of the coal. These believe that oxidation of the carbon and hydrogen of the coal is hastened by the action of the water present. This latter view seems to be based on the fact that moisture has seemingly, in some instances, greatly increased the deterioration of practically non-pyritic coal.

That an increase of temperature has much to do with increasing the activity of the other deteriorating agents is the general belief. This rise of temperature, whether coming from outside sources or physical or chemical action within the coal, tends to accelerate the absorption of oxygen and thereby increases the oxidation going on and also evaporates the gases which may still be occluded in the coal. Thus heat assists in decreasing the fuel value of the coal and at the same time increases its liability to ignition. That the exclusion of oxygen

from coal will decrease its loss in heating value is a growing belief.

From the evidence at hand, therefore, it would seem that not only do observers differ widely as to the causes and extent of weathering, but no very exact study of the problem has been made in all of its phases on which could be based very much either of theory or fact concerning the deterioration of coal in storage.

Any discussion of the matter from our own standpoint will be reserved until after presenting the results of our experiments as outlined in the following pages.

EXPERIMENTAL WORK.

It seems necessary to concede at the outset that coals will differ as to the extent of their deterioration, because of their individual peculiarities of either a chemical or physical nature. It should be said at the outset, therefore, that in the present studies no attempt has been made to include all types of bituminous coals, but only those of the Illinois field. In this series an effort has been made to cover a number of localities furnishing a fair representation of the different coals of the State. Briefly outlined the conditions under which the coals were studied were as follows. The starting point was the coal in its normal state, that is, as nearly as possible corresponding to the condition existing when broken out of the vein. The period of time between the mining of the coal and the initial analysis varied somewhat, but the first series of tests was made as soon as possible after the coal was mined. In the light of subsequent developments greater stress should be put on the early examination of samples to determine the initial condition. Even under the most careful disposition of samples in laboratory containers, a deterioration takes place which, while not exactly a "weathering" process, is still a large element in any study of the case and must be considered if exact conclusions are to be available.

There were nine initial samples taken of approximately 100 pounds respectively. The coal was of small lump or nut size,

and each sample was subdivided in order to subject the same kind of coal to various conditions. These conditions were to be continued through nine months, and in general were:

(a) Outdoor exposure.

(b) Exposure to a dry atmosphere at a somewhat elevated temperature ranging between 85 degrees and 120 degrees Fahrenheit.

(c) Under the same conditions as (b) so far as temperature was concerned, but to be drenched with water two or three times per week.

(d) Submerged in ordinary water at a temperature approximately 70 degrees.

The periods for examination were divided as nearly as the work would permit into

1. The initial analysis of the fresh coal.
2. After exposure for five months.
3. After exposure for seven months.
4. After exposure for nine months.

For the sake of comparison also the calorific values were determined under uniform conditions throughout by means of the Parr calorimeter and the results calculated to the ash and water free basis to eliminate any variations in the process of sampling and to make, as far as possible, the different samples as well as the different lots comparable among themselves.

Concerning the results it should be noted that while experiments are of a preliminary nature, largely devised to gain information for carrying out more elaborate and comprehensive tests, they are sufficiently consistent among themselves to justify certain tentative propositions, as follows. There is evidence, first of all, of a distinct difference between the submerged coal and that which was exposed to the air. The values found for the submerged coal throughout the nine months did not vary, with possibly one or two exceptions, by greater amounts than would occur in tests made on succeeding days by the same operator. Values obtained so far apart as to time, with the inevitable modifications due to tempera-

ture, atmospheric conditions, etc., may fairly be considered as checking if they agree within 100 or 150 units. There may indeed seem to be a uniform tendency to fall slightly in values, but from the showing the submerged coal may very fairly be said to remain constant.

If we consider next the outdoor exposure, it should be said that these samples were contained in shallow boxes placed on the nearly flat roof of a building and subjected to the changes of temperature and moisture common to the months from October to July. The coals varied somewhat in their tendency to crumble, but all showed more or less of the "slaking" process. The remarkable fact in this series is the wide variation in the amount lost, ranging from approximately 2 to 10 per cent. The question naturally arises as to whether this a natural characteristic of the different coals or whether the same variations would be found under different conditions, as, for example, the storing in large masses instead of the small lots worked with. Attention should also be called to the fact that during the progress of this work, as will be shown under another topic, proof was obtained of the positive loss of values in samples stored under supposedly the best laboratory conditions. The rate of progress of this loss has not been determined, though it is presumably slow. The effort was made to obtain the initial values on all the samples to be subjected to weathering at the earliest possible date after being mined, but variations as to time were inevitable, and the importance of guarding this point was not so fully appreciated at the outset as it was at the close of the work.

In further studies along this line this particular element in the case will be guarded with due care, but there is no evidence so far that the results would be materially affected or would be different from the general indication of the charts.

Not the least striking of all the results are those obtained from coal stored in a thoroughly dry atmosphere. The fact that these samples lost in the aggregate quite as seriously as those exposed to outdoor conditions, and, if anything, even to

a greater extent, would seem to indicate that moisture has little to do with the processes of deterioration. It must be conceded, of course, that, so far as relates to the weathering out of pyritic sulphur, moisture is an essential condition, but the losses are so much greater than would be represented by the leaching out of sulphur that this element is practically obliterated as a factor in the results. If anything is proved indeed concerning the effect of moisture, it is that it retards rather than accelerates the loss of heat.

Other facts than these just cited substantiate the above feature of the case, tending to show that, after all, weathering is not a leaching process, or one which primarily results from the direct action of water and attendant weather conditions, but seems to be a direct loss of volatile hydrocarbons. To how great an extent there is a reabsorption of atmospheric gases and to what extent oxidation accompanies such absorption cannot be stated from this series of experiments. That water indirectly is a factor cannot be doubted, for anything which promotes disintegration facilities the escape of combustible gases. Disintegration results from handling, from freezing and thawing, and from the decomposition of pyrites. In general, we would expect greater persistency of values in the dense and less friable coals and in those with less of iron pyrites throughout their texture. In submerged coal the decomposition of the pyrites is checked and without special reference to fineness of division. The loss of volatile matter seems also to cease. These processes, which are active in the air and cease under water where the element of pressure or lack of it can hardly be a factor, suggest the idea of displacement of hydrocarbon gases by oxygen, by some process akin to osmosis or catalysis, whereby a certain amount of oxidation of the carbon or hydrogen occurs. Altogether, the results are of value, not only as touching the facts relating to the storage of coal, but especially as to their suggestions for further studies looking to fuller information of practical value on this very important topic.

SUMMARY.

(a) Submerged coal does not lose appreciably in heat value.

(b) Outdoor exposure results in a loss of heating value varying from 2 to 10 per cent.

(c) Dry storage has no advantage over storage in the open except with high sulphur coals, where the disintegrating effect of sulphur in the process of oxidation facilitates the escape of hydrocarbons or the oxidation of the same.

(d) In most cases the losses in storage appear to be practically complete at the end of five months. From the seventh to the ninth month the loss is inappreciable.

(e) The results obtained in small samples are to be considered as an index of the changes affecting large masses in kind rather than in degree, but since the losses here shown are not beyond what seems to conform in a general way to the experience of users of coal from large storage heaps, it may not be without value as an indication of weathering effects in actual practice.

THE DETERIORATION OF COAL SAMPLES.

Closely related to the weathering of coals is the subject of the deterioration of samples in storage. It would be assumed as a general proposition that carefully-sealed samples, kept at normal temperature, in glass retainers, would remain constant as to their composition. Many facts have accumulated which seem to disprove this proposition. In an article by one of the writers* reference is made to the necessity of making calorific determinations, where comparisons between different instruments are involved, at approximately the same date. To quote from that article: "A comparison of calorimeters should be made at approximately the same time. A series of calorific determinations made on finely-ground samples on May 12, 1900, was found to give a reading 2.4 per cent. less on July 12, 1900. It was necessary to repeat practically all of the above determinations on this account, all of the results

*A New Coal Calorimeter, by S. W. Parr, "Jour. Am. Chem. Soc.," Oct., 1900, p. 650.

showing a deterioration in the finely-ground samples. This subject will receive further attention later."

In correspondence and conference with other workers this fact has been questioned, as, for example, Dr. Bunte, of the Karlsrhue Polyteknikum, says that coal samples kept for analytical purposes, and which are determined by students year after year, give evidence of a constancy as to their calorific values. However this may be, the coals of the Mississippi Valley, being of a different type from the German coals, may not necessarily follow the same behavior in storage. Indeed, it may be doubted if the coals of Western Pennsylvania and Virginia would show the same behavior in this respect as the coals of the Mississippi Valley. At any rate, there have accumulated a number of facts which point to the deterioration of Illinois coal samples in laboratory storage, and it is the purpose of this paper to give the evidence which has come to hand up to the present time.

The matter is of importance, not only from its bearing upon an understanding of the matter of the weathering of coals, but in connection with all matters pertaining to the comparison of values as between different samples. It is to be taken into account also in considering the value which is to be placed upon the "pure coal" idea as frequently set forth, to the effect that the ash and water free basis is common ground for comparison under all conditions. It is exceedingly helpful and, indeed, essential, in the scientific study of coals, to have a unit of reference which may be used as a basis of comparison, but it is essential also to know the variations which may enter into such a unit, in order to avoid errors in the ultimate conclusions.

In comparing the values of Illinois coals, as obtained by the United States fuel-testing plant at St. Louis, with the values determined in this laboratory by the Illinois State Geological Survey on coals from the same districts, it was found that considerable discrepancy existed upon referring the results in both cases to unit basis, as, for example, the ash and water free condition. Perhaps the most striking fact

in this connection was the uniformly lower calorific values obtained by the State Geological Survey. The possibility of this difference being due to variations in methods and to different operators was duly considered. However, the method of sampling at the mine was the same, the sample being taken from the face of the vein, reduced by quartering in the usual manner to about two pounds in weight, sealed in tins with screw cap and insulating tape, exactly as followed by the fuel-testing plant at St. Louis.* The type of calorimeter was also duplicated, the instrument in this laboratory used in this comparison being of the Mahler-Atwater type with platinum lining and operated in a room under temperature control. A careful standardization of the instrument and a redetermination of its water equivalent were also made. The results here were so uniformly lower than those obtained at St. Louis as to call for a special study to ascertain the cause. An examination of the accompanying table will make evident the difference in calorific values as above described.

It is not a sufficient explanation to say that the samples in the two cases were not identical. Indeed, frequently they were not taken from the same mine. It is a well established fact, however, that samples taken from the same locality, when referred to a unit basis, as the ash and water free conditions, will show relatively small variations, at least within a limited area. It is true that variations in the same region do occur often; evidence of these variations is largely dependent upon the accuracy of the unit adopted for reference, and, when properly compared, these variations are not of sufficient size nor of sufficient uniformity to explain either the magnitude or the constancy in direction of the differences shown in the accompanying table. Concerning the unit of reference, it should be said that the ash, moisture and pyrite-free basis is used as approaching the nearest possible to the actual material under consideration, thereby eliminating such variables as would obviously result if no notice were taken of the presence or absence of sulphur. The weight of ash, therefore, is

*U. S. Geol. Surv. Coal-Testing Plant, Bul. 261, p. 20.

corrected by adding $\frac{5}{8}$ of the weight of sulphur present, as representing the original pyritic condition.

In taking up the study of the conditions under which the work was carried on in the two laboratories, so far as can be determined, the only point of divergence seemed to reside in the time elapsing between the date of sampling at the mine and the date at which the determinations were made in the laboratory. In the case of the fuel-testing plant at St. Louis this difference in time was relatively short, being presumably, as a rule, not more than two or three weeks. In the case of the State Geological Survey, because of certain exigencies, an unavoidable delay occurred, hence the time elapsing varied from six months to a year.

Two methods of caring for the samples were followed. First, where time permitted, the coal as received in the tins was at once emptied into shallow pans and the amount of moisture lost upon air drying was determined by allowing the pans to stand exposed to the air over night. The sample was then reduced to buckwheat size, one-half was sealed in glass jars of the so-called Lightning or Putnam pattern and the other half was ground in the Ball mill with porcelain jars of the Abbe type. This part of the sample was also sealed in a similar jar and set aside for the analytical work later. The analyses used in Table 1 for comparison with the St. Louis results were made on these finely-ground portions.

The other method of caring for the samples consisted in simply transferring the coal as received in the tins to glass containers without air drying. Fifty samples were thus disposed of, about half being stored in the Putnam jars and half in jars of the common Mason type.

As already noted, it has been impossible in this table of comparisons to select cases where the samples were exact duplicates from the same mine in each instance, but it may fairly be claimed that the uniformity with which the lower values are indicated for the older samples precludes the possibility of ascribing the difference to the character of the coal. The

TABLE 1.—COMPARISON OF NEW AND OLD SAMPLES OF ILLINOIS COALS IN LABORATORY STORAGE.

Sample numbers.	Locality.	Mine sample U. S. G. S.—Ash, moisture and pyrite free.	Mine sample, Ill. G. S.—Ash, moisture and pyrite free.	Difference.	Per cent. of variation.
U. S. G. S., Ill. No. 1.....	O'Fallon.....	14,567	...	...	...
Ill. Geol. Surv. No. 95.....	O'Fallon *a*.....	...	14,084	483	-3.31
U. S. G. S., Ill. No. 3.....	Marion	14,561	...	...	...
Ill. Geol. Surv. No. 330...	Marion *a*.....	...	14,335	226	-1.55
U. S. G. S., Ill. No. 9.....	Staunton	14,615	...	...	...
Ill. Geol. Surv. No. 94.....	Staunton *a*.....	...	13,923	692	-4-72
U. S. G. S., Ill. No. 10....	W. Frankfort....	14,647	...	...	...
Ill. Geol. Surv. No. 364...	W. Frankfort *b*..	...	14,332	315	-2.15
U. S. G. S., Ill. No. 11....	Carterville.....	14,731	...	...	...
Ill. Geol. Surv. No. 325...	Carterville *a*.....	...	14,213	518	-2.15
U. S. G. S., Ill. No. 15....	Centralia	14,587	...	...	...
Ill. Geol. Surv. No. 167...	Centralia *b*.....	...	14,200	387	-2.65
Ill. Geol. Surv. No. 169...	Centralia *a*.....	...	14,376	211	-1.44
U. S. G. S., Ill. No. 16....	Herron.....	14,558	...	...	...
Ill. Geol. Surv. No. 323...	Herron *a*.....	...	14,321	237	-1.62
U. S. G. S., Ill. No. 18....	LaSalle.....	..	14,722	...	...
Ill. Geol. Surv. No 393....	LaSalle *b*.....	14,440	...	282	-1.91

(*a*) Not same mine. (*b*) Same mine.

same thing may also be said with reference to variations in results which may be expected from different operators. If this were the reason for the discrepancy, one would hardly expect the uniformity as to direction of the results here indicated in the tables. To determine whether deterioration might result from the finely-ground state of the samples, the reserve sample in the coarse condition in a number of cases was taken and calorific determinations made as upon the fine samples. These results were found practically to duplicate those obtained upon the ground samples. Hence, it was concluded that if deterioration were the explanation, it had affected both the coarse and fine samples alike. It was then

decided to obtain new samples from the same localities and so far as possible from the same mines, collecting and preparing the samples in exactly the same way as before. The determinations on these samples were made within a period not to exceed ten days from the date of collection. The results, ar-

TABLE 2.—COMPARISON OF COAL SAMPLES FOR VARYING LENGTHS OF TIME IN LABORATORY STORAGE.

Lab. No. Ill. State Geol. Survey.	Source of sample.	Time of storage.	B. t. u. of ash, moisture and pyrite free.	Loss in B. t. u.	Percentage of loss.
421	Majestic Mine, Duquoin, Ill., April 17, 1907	10 days	14,386	...	...
307	Paradise Coal & Coke Co., Duquoin, Ill	1 year	14,116	207	-1.9
459	Big Muddy C. & I., No. 7, April 18, 1907	10 days	14,615	...	...
323	Squirrel Ridge Mine, Herrin, Ill	1 year	14,321	294	-2.0
460	Big Muddy Coal Co., No. 8, Clifford, April 18, 1907	10 days	14,615	...	...
325	Clifford, Carterville	1 year	14,213	402	-2.7
462	Peabody Coal Mine, No. 3, three miles west of Marion, Ill., April 18, 1907	10 days	14,781	...	...
330	Peabody Coal Co., Marion, Ill	1 year	14,335	446	-2.6
540	Sangamon Mine, Springfield	1 week	14,567	...	...
82	Sangamon Mine, Springfield	7 months	14,100	467	-3.2
81	Sangamon Mine, Springfield	7 months	13,940	841	-4.3
557	Kelly No. 4, now Dearing No. 44	5 days	14,450	...	...
332	Kelly Coal Co., Westfield, Ill	1 year	14,054	396	-2.8
558	Kelly Coal Co., Himrod Mine, Himrod, Ill	5 days	14,564	...	...
333	Himrod Mine, Himrod, Ill	1 year	14,087	477	-3.3

ranged for comparison with the old samples, are shown in Table 2. The striking uniformity with Table 1 is to be noted in that practically the same difference in values is shown between the new samples and the old as exists between the St. Louis results, presumably also on fresh samples, and our own results known to be on samples of from six months' to a year's standing.

TABLE 3.—COMPARISON OF ILLINOIS COAL SAMPLES WITH RELATIVELY SHORT PERIOD IN LABORATORY STORAGE.

Sample numbers.	Locality.	Mine sample U. S. G. S.—Ash, moisture and pyrite free.	Mine sample Ill. Geol. Surv.—Ash, moisture and pyrite free.	Difference.	Per cent. of variation.
U. S. G. S. Ill. No. 3.....	Marion.....	14,561	...	...	...
Ill. Geol. Surv. No. 462.....	Marion *a*.....	...	14,781	220	+1.51
U. S. G. S. Ill. No. 7.....	Collinsville.....	14,373	...	...	...
Ill. Geol. Surv. No. 725.....	Collinsville *b*...	...	14,659	286	+1.98
Ill. Geol. Surv. No. 723.....	Collinsville *a*...	...	14,640	267	+1.85
Ill. Geol. Surv. No. 724.....	Collinsville *a*...	...	14,564	191	+1.32
U. S. G. S. Ill. No. 9.....	Stanton.....	14,615	...	...	...
Ill. Geol. Surv. No. 737.....	Stanton *a*.....	...	14,301	314	—2.14
U. S. G. S. Ill. No. 11.....	Carterville.....	14,731	...	...	...
Ill. Geol. Surv. No. 460.....	Carterville *b*....	...	14,615	116	—.787
U. S. G. S. Ill. No. 14.....	E. Springfield..	14,464	...	...	...
Ill. Geol. Surv. No. 540.....	E. Springfield *a*	...	14,567	103	+.711
Ill. Geol. Surv. No. 740.....	E. Springfield *a*	...	14,408	56	—.387
Ill. Geol. Surv. No. 741.....	E. Springfield *a*	...	14,429	35	—.243
U. S. G. S. Ill. No. 16.....	Herron..	14,558	...	...	+.391
Ill. Geol. Surv. No. 459.....	Herron *b*.....	...	14,615	57	
U. S. G. S. Ill. No. 19.....	Ziegler.....	14,601	...	...	...
Ill. Geol. Surv. No. 419.....	Ziegler *b*.....	...	14,480	121	—.829
Ill. Geol. Surv. No. 420.....	Ziegler *b*.....	...	14,445	156	—1.06

a Not same mine. *b* Same mine.

Still a third series of results has been arranged in Table 3. Here the comparison is made between the St. Louis values and our own, obtained on relatively fresh samples from the

same or near-by mines. There is further confirmation of the proposition here in that the results on our own samples are sometimes higher and sometimes lower than the St. Louis values. The relative dates are not at hand in each case to indicate whether or not the plus and minus values conform to a greater or less transpiration of time before analysis, but it is worthy of noting that the discrepancies are not so wide as in Tables 1 and 2, where a positive and wide variation of time existed. Even in the third sample from Stanton (Table 3), where a difference of 2.14 per cent. is indicated, in Table 1, for the same mine, a difference of 4.72 per cent. is given.

It is now in order to refer to certain other facts which still further confirm the proposition in hand. The fifty samples above referred to as having been transferred without air drying to glass containers upon their arrival at the laboratory, were examined after about ten months' standing. Twenty-nine of the samples had been placed in the type of jar known as the Lightning or Putnam jar. Extended experience with this jar as a container for sodium peroxide, a chemical with unusual avidity for moisture from the atmosphere, has proved it to be possessed of an absolute seal. The remaining twenty-one samples had been placed in the common Mason fruit jar with metal screw cap and very indifferent seal. After the ten months of storage, upon opening the Lightning jars a slight pressure of gas was noted which suggested the testing of the same with a lighted match. In twenty-six of these jars the gas ignited with a strong blue flame, burning up from one-half to six inches above the top of the jar. Upon covering with the cap and testing again with a match, these jars would reignite for two or three successive times. Two of the jars had been previously opened without attention to the contents and it is not known whether they contained inflammable gas or not. In one other of these jars the gas was carbon dioxide, judging from the fact that instead of igniting the match was extinguished. Not one of the Mason jars with the zinc cover contained any pressure of gas and no tendency to ignite was manifested. It should be

noted that all of these jars were in diffused light, but not in direct sunlight, and that only the Lightning jars possessed perfect seal. We have herein evidence of the tendency of the coal to give off combustible gas after being broken out of the vein, and if we accept the theory proposed by Richter and others, that this exudation of combustible gas is accompanied by a corresponding absorption of oxygen from the air, we may readily understand some of the processes which go on in the deterioration of samples as well as in the weathering of coal.

One further incident is worthy of notice in this connection. Certain samples used in Coal Bulletin 2, published as the University of Illinois Studies on the Composition of Coal, 1904, were opened after three years of storage in jars of the Lightning type. These samples had not been opened during the three years. It was noted that much of the iron pyrites disseminated throughout the coal had become oxidized to ferric sulphate. This suggested that by leaching out this compound, and estimating the sulphur thus transformed to sulphate, we could calculate the amount of oxygen necessary to bring about the reaction from the form of iron pyrites, (FeS_2) to ferric sulphate, $Fe_2(SO_4)_3$. It was found that the amount of oxygen required to oxidize the weight of sulphur found was 1.99 grams, and calculated to the equivalent volume of pure oxygen would be 1.39 liters, or, if calculated to the equivalent of atmospheric air, it would require 7 liters of such air to furnish the necessary oxygen for the reaction. When it is remembered that the jars in which these samples were kept had a volume all told of only one pint and that this space was occupied at least to the extent of three-quarters of the total with coal of buckwheat size; and when we further remember that these jars were possessed of absolute seal, without opportunity for transference of oxygen from without, there is furnished evidence of the fact that occluded oxygen or absorbed air must have been present in sufficient amount to accomplish the work indicated by the transformation of the pyrites to ferric sulphate.

It would seem from the above experiences that there is not

only sufficient evidence to establish the fact of the deterioration of coal samples, but a fairly well established explanation as to how this deterioration takes place. Other tests along this same line are being carried out from still other standpoints, and, while they are not complete, the evidence is all in the same direction as that adduced above.

SUMMARY.

(a) An exudation of combustible gases from coal occurs from the time of breaking out of the sample from the vein.

(b) An absorption of oxygen accompanies the exudation of hydrocarbons.

(c) Samples of coal in most carefully sealed containers are subject to deterioration.

(d) The process of deterioration is probably due to oxydation of hydrogen or hydrocarbons by means of the absorbed oxygen. It may also be due to a simple loss of combustible gases and the replacement of the same by non-combustible gases such as oxygen.

(e) The rapidity or extent of this deterioration varies with different coals, but is probably most active during the first two or three weeks from the taking of the sample, but does not seem to reach a normal state till after a few months have elapsed. Further data on this point especially are necessary.

It is interesting, also, to bring together the averages of the results in the three tables for further comparison. There is thus afforded further evidence suggesting the fact of deterioration.

TABLE 4.—AVERAGES FROM TABLES 1, 2 AND 3.

Illinois State Geological Survey—Eight old in comparison with eight new samples—from Table 1	Average 2.85 per cent. lower.
Illinois State Geological Survey—Nine old samples in comparison with nine results by U. S. G. S.—from Table 2	Average 2.40 per cent. lower.
Illinois State Geological Survey—Twelve fresh samples in comparison with results by U. S. G. S.—from Table 3	Average 0.20 per cent. higher.

THE FASTEST SHIPS IN THE WORLD.

At the beginning of every year it is customary to review the progress made in shipbuilding during the previous twelve months, and by picking out the salient features of each contributory line of evolution to strive to form the best idea of the directions of greatest progress or the tendencies of future development. Two facts stand out at present above all others. The first, affecting merchant steamers alone, is the enormous improvement in the comfort and luxury of ocean voyaging; the second, with which we are now concerned, is the great rise in absolute speed which, though very marked in special cases in the mercantile marine, is much more general in the warships of the world. It is, however, impossible to form any opinion of value by simply considering the progress of one particular year, and we propose to deal with the growth in speed since the beginning of the century.

It is a very simple matter—given the money—to produce a small vessel of abnormal speed. Cases such as the famous *Arrow* or the *Turbinia*, in which absolutely everything is sacrificed to pace, do not represent, by any means, the acme of naval architecture. Interesting they certainly are, but their use and value are doubtful and transitory. When, however, it becomes a question of attaining not only a very high speed, but of *maintaining* it, and of carrying weight in addition, be it cargo or coal, guns or armor, the problem becomes different and more difficult, while if, in addition to this, the vessel must be commercially profitable, the conditions become extremely hard to fulfill. The case of the recent Cunard vessels is one of the most up-to-date examples available. In warships, of course, the question of cost hardly enters, and use can be made of designs or materials that dividend-earning concerns could not afford, and in which at the same time there is neither the need nor the inclination to take the risks or reduce the margins that are accepted in naval work. The two cases must, therefore, be treated separately.

For a floating ship-shaped body propelled on the surface of

the water speed has also a relative value, the real measure being its ratio to the square root of the length, viz: $\frac{V}{\sqrt{L}}$ where V is speed in knots and L is length in feet. In cases where the value lies between 0.5 and 0.7 the ship is being driven at a very moderate and economical speed; between 0.7 and 1.0 we find the speed of mail steamers and battleships, and between 1.0 and 1.3 we get cruisers and channel steamers. Beyond 1.35 we cannot go in full-sized vessels under present conditions, because it is not possible to get enough engine and boiler power into the ships, on account of the fact that the floor space available in the ships is not sufficient; but it can be done in torpedo craft by using very high-speed engines and excessive forced draft to the boilers. In these ships the ratio of $\frac{V}{\sqrt{L}}$ is between 1.8 and 2.2, and only in very exceptional cases has the latter ratio yet been exceeded. The reason underlying the importance of this ratio is that the wave-making resistance of the ship does not increase regularly, but in humps of varying magnitude, the first of which occurs at a speed of about 1.4 to 1.6 times $\sqrt{L}$. From the above it follows that speed should always be considered relatively as well as absolutely.

WARSHIP SPEEDS.

One of the earliest and relatively fastest vessels built was the *Forban* of the French Navy, which was constructed by Normand at Havre in 1895. She attained 31.2 knots, though only 144 feet long, displacing 125 tons and requiring 3,950 I.H.P. For some years she held the record for speed, and was always a remarkable vessel, her success being almost entirely due to her exceptional machinery. The *Turbinia*, early in 1897, was the first vessel to break the *Forban's* record. Up to 1900, about eighty vessels had been built which had, on genuine official trials, attained a speed of 30 knots. Sixty of these were in the navies of England (48) and

Japan (12). They were all propelled by reciprocating engines, and for the most part averaged from 210 to 215 feet in length by 20 to 22 feet breadth. The power was about 6,500 I.H.P.

In 1900, however, the trials of H. M. S. *Viper* astonished everyone. This vessel still holds the record for speed, having attained over 37 knots when displacing 370 tons. She was of exactly the same dimensions as the 30-knotters, but with larger boilers—having 275 square feet of grate area, compared with about 220 in the other ships, the respective heating surfaces being 15,000 and 12,000 square feet. The *Viper* was the first vessel to be fitted with Parsons turbines (except the *Turbina*), and the results of her trials are given in Table I. The turbines weighed about 7½ per cent. less than the reciprocating engines of only half the power fitted in the sister ships.

TABLE I.

Trial.	Speed in knots.	Equivalent I.H.P.	R.P.M.	Coal burned per hour, pounds.	
				Total.	Per I.H.P.
Maximum power (1 hour)	37.113 max. 36.58 mean	13,000	1,180	34,500	2.61
3-hour coal consumption	33.83	10,300	1,050	25,700	2.49
3-hour official trial	31.118	8,350	950	19,800	2.38
12-hour slow speed	15.0	750	450	3,000	4.03

The *Viper* was lost by running ashore, and the *Cobra*, a very similar vessel of slightly slower speed, broke her back through structural weakness and sank in the North Sea. The loss of the *Cobra*, coupled with signs of weakness in many of the 30-knotters, resulted in a change of policy in the construction of these high-speed vessels, and structurally heavier hulls were afterwards required, the consequent sacrifice in speed being accepted. In England, therefore, between 1901 and 1905 no really fast destroyers were built for the British Navy. One exceptionally fast vessel, the *Mode*, was built by Yarrow for the Swedish government in 1902, a speed of 32.4 knots being obtained; but in other navies no attempt was made to exceed 30 knots—in fact, Germany was content with 27 knots and France and Italy with about 28. Until

this year hardly any new torpedo craft have been constructed in the United States for some years.

Towards the end of 1905, however, the British Admiralty laid down five ocean-going destroyers, most of which have just completed their trials. These vessels and the subsequent batches of two laid down in 1906 and five in 1907 are all about 250 to 280 feet long, and displace about 850 tons. The speeds attained on a six-hour trial have varied from 33.14 in the *Cossack* to 34.3 in the *Mohawk*, which latter at present holds the record for being the fastest ship afloat.* Propelled by Parsons turbines of about 17,000 horsepower, these vessels are very remarkable in many ways. They carry a poor armament (only three 12-pounders and two 18-inch torpedo tubes), but are especially built for sea keeping in company with the fleet. They carry 160 tons of oil fuel.

Another remarkable vessel, *G137*, was completed in 1907 by the Germania Company, at Kiel. Also propelled by turbines, *G137* is extremely similar to the British River-class boats of 26 knots speed that were built in 1903 and 1904. She attained a speed of 33.1 knots on her trials at 580 tons displacement, and carries no less than four torpedo tubes, one 15-pounder and four smaller guns.

The extraordinary success that attended the speed trials of all these very fast vessels of 1907 has gone a long way to assure naval architects of the success of H. M. S. *Swift*, which is by far the most remarkable ship now under construction, from the speed point of view. Built for a speed of 36 knots on an eight-hour trial under service conditions, the vessel displaces no less than 1,800 tons on 10 feet 6 inches draught. The armament will include four 4-inch guns. The ship was launched on Dec. 7, 1907.

Table II shows the leading dimensions and speeds of all these vessels, together with the dates of their trials. The years 1903, 1904, 1905 and 1906 do not show any progress of importance, 30 knots being the extreme speed attained, and

* Eclipsed by the sister boat *Tartar*, which, on December 17, averaged 35.36 knots for 6 hours, and made 1 mile at the rate of 37.037 knots.

most navies contenting themselves with slower vessels of more durable construction. The performance of *G137* is remarkable in that it was attained with coal fuel. Oil fuel seems likely to become an absolute essential in the design of these very fast craft, for it admits of several advantages which cannot be ignored :

(1) Greater calorific value, giving either greater radius of action on same weight of fuel, or less weight for same radius.

(2) Greatly reduced stokehold space required, especially in a fore-and-aft direction.

(3) Greater ease of manipulation.

It is interesting to note how the length of these vessels has increased in proportion to the speed; the ratio has remained very constant during the last seven years.

TABLE II.

Vessel.	Date.	Length, feet.	Speed, knots.	$\frac{V}{\sqrt{L}}$	Horse-power.	Dis-place-ment, tons.	Horse-power per ton *D*.	Admiralty coefficient.
Forban	1895	145	31.2	2.59	3,950	125	31.6	192
Turbinia	1897	100	33.0	3.3	2,200*	44.5	49.5	205
English Navy	'98-'00	210	30.0	2.07	6,500	320	20.3	194
Japanese Navy	1899	220	31.0	2.09	7,000	315	22.2	197
Viper	1900	210	37.0	2.55	13,000*	370	35.1	200
Mode	1902	220	32.4	2.175	7,500	400	18.8	246
G 137	1907	235	33.1	2.16	13,400*	580	23.1	188
Cossack†	1907	270	33.2	2.02	17,500*	830	21.1	185
Swift††	1908	345	36.0	1.94	33,000*	1,800	18.3	209

* Turbine machinery. † Oil Fuel.

TABLE III.

Vessel.	*Swift.*	*Sentinel.*	*Amethyst.*	*Encounter.*
Length, feet	345	360	360	355
Breadth, feet	35	40	40	56
Displacement	1,800	2,800	3,000	5,800
Speed, knots	36	25.5	23.6 (21 75 design)	21.0
Horsepower	33,000	17,500	14,000 (10,000 design)	12,000
Armament	4 4-inch 0 tubes	10 12-prs. 8 1½-prs. 2 tubes	12 4-inch 8 3-prs. 2 tubes	11 6-inch 9 12-prs. 2 tubes
Protection	nil	armored deck	armored deck	armored deck
Coal at normal draught	180 tons (Oil fuel)	150 tons	300 tons	500 tons
Date	1908	1905	1904	1902
$\frac{V}{\sqrt{L}}$	1.94	1.344	1.245	1.13

In all these cases we have considered vessels of abnormal absolute speed, in which great sacrifices of armament and

protection have been made to secure pace. We shall proceed next to work back to vessels of the cruiser type, which are also relatively high-speed vessels. The first step in the connection is obviously through the *Scout* class of cruiser, and as it happens that these vessels are remarkably similar in general dimensions to the *Amethyst* type of third-class cruiser, we have compared these vessels in Table III, adding the most recent type of second-class cruiser. After this point in British naval practice there is a radical change. The size of vessels necessitates their being protected by external armor, and the necessary compromise of weights involves a reduction in machinery. We then begin to get to comparatively slow proportionate speeds. Thus, for instance, the very fast cruisers of the *Good Hope* and County classes of 500 and 440 feet in length, have speed-length ratios of only 1.075 and 1.1, respectively.—"International Marine Engineering."

THE APPLICATION OF MOTORS TO MACHINE TOOLS.*

BY DEXTER S. KIMBALL.

The introduction of electrical distribution and the electric motor gave to engineers of large plants a solution to a problem that had for a long time been very troublesome. The old method of power distribution with its wide belts and large shafts, and when the plant was large its detached engines and sometimes boilers, was quickly recognized as far inferior to the new method. By this method the great friction losses due to large shafts and belts were eliminated and centralization with its accompanying economy could be carried to its highest form. The larger the plant the greater was the advantage to be gained, so that it quickly became good practice to distribute power electrically, and run the various lines of small shafting by motors belted to them.

By an easy extension of this system the larger tools were soon belted to their own individual motors and the advantages

* Taken from the Proceedings of the combined Electrical and Mechanical Engineering Societies of Cornell University.

so gained were evident to all, and up to this point engineers were fairly well agreed. But engineers soon came forward with the claim that great economy could be obtained by attaching a motor to every tool and doing away with all belts and shafts. On this point, however, engineers were not so unanimous, and a discussion arose as to the relative merits of the two systems and many tests were made to determine which was the most economical way, these comparisons generally being drawn between the so-called *group system* and *individual-motor system.*

This method of comparison while in general not unfavorable to the individual motor was not conclusive, for the reason that the item of power is a small one in most manufacturing establishments, and a very great saving must be effected by any system to make economy a determining factor. To illustrate: An electrical manufacturing establishment, and these are heavy users of power, employing say 1,000 men would require at least 500 H.P., which, with coal at $6.00, would cost about $9,000 or $10,000 a year. The output of such a place should be in the neighborhood of $1,500,000 at factory cost. The question of economy alone was not sufficient to settle the problem, but out of the discussion came much valuable data and some well defined principles. It was clearly shown that conditions exist where either or both systems have a place, and that again conditions may exist where neither are desirable, as in cases where heavy machinery is to be operated close to the prime mover, as in certain kinds of mills driven by water wheels.

The plant must be very small and compact, however, when electric distribution cannot be used to advantage, and in large plants it is indispensable.

It is also now conceded by engineers in general that large and portable tools can be best driven by individual motors, and the greatest bone of contention in this regard is the question of just how far individual driving should be used as against group driving, with a gradual growing sentiment in favor of the individual drive.

That the individual drive has not met with more favor was due in the past mainly to two causes:

(1) Imperfect motors.

(2) The general attitude of machine-tool builders.

When motors were first introduced in this work electrical designers had not studied the peculiar problems presented, and as a consequence the first motors were not very satisfactory. The machine-tool builder, on the other hand, saw at once that the motor was going to impose a new set of conditions on these machines, compelling him eventually to alter his patterns; and many of them naturally did much to discourage what some of them characterized as a fad.

As might be expected, the combinations designed under these circumstances were fearful and wonderful. A standard gas engine fastened to an ordinary carriage would not make a very good automobile; yet in comparison it would show up well with some of these early efforts.

But these difficulties are now being rapidly overcome. Machine-tool builders and electrical men are getting together on the problem, and it will not be long till growth or consolidation will give us a machine company which will make a specialty of turning out complete motor-driven tools. When that time comes, and only then, will the individual drive reach its highest development and lowest production cost. The latter item will have a great bearing on the final adjustment of the question of group drive versus individual driving, as will be seen later. In the meantime it is possible to buy almost any machine tool, motor driven in some way, although not always in a very desirable manner.

With these general principles established the engineer is confronted with the problem of connecting up his electrical system of distribution to his medium-size and small machines, and in making his decision as to the method to be used he will be governed largely by the following considerations:

(1) First cost of installation.

(2) Maintenance and depreciation.

(3) Provision for extension.

(4) Sectional operation.
(5) Flexibility as to location of tools.
(6) Efficiency of system.
(7) Positive application of power.

It may be well to consider these points in some little detail.

(1) Undoubtedly the first cost of individual driving is considerably greater than group driving, and, unless it can be shown that the individual drive has great advantages in other ways which offset this important item, it is not likely to be considered by the man supplying the money. This is often a very difficult thing to do, and first cost will remain a drawback to the motor drive for small tools till different conditions of manufacturing reduce the costs considerably from where they stand at present.

(2) On the second point we have as yet not a great deal of data that the writer is aware of, but his experience has been that the cost of maintenance and the depreciation was somewhat less in group driving. In the group drive the great item of expense is that of belting, which is costly and wears out rapidly; on the other hand, when motors do need repairing the repairs are costly, so that, on the whole, there does not seem to be much choice. Reliable data on this point would be of great service.

(3) Regarding the third point, the individual drive has all the advantage. No system has ever been devised that provides so easily for extension. Changes in arrangement are also more quickly and easily made with the individual drive.

(4) Here, again, the advantage is all with the individual drive, particularly with large tools which may be required to run overtime. Further, the breaking down of an individual motor does not affect but the one tool. This last, however, is not of great importance, as the motors now built are quite reliable.

(5) On this point the individual drive has an advantage that is particularly important. Machines so driven can be placed wherever desired, and in case of large tools, ideal con-

ditions are obtained for overhead-handling devices. In the case of small tools greater convenience can be obtained and tools can be placed in the middle of the room without cutting out the light. Incidentally, the elimination of belts on such a floor greatly decreases the dust.

(6) The question of efficiency has already been discussed and needs no further comments here except that it has been found by actual measurement that there is little to choose between group and individual driving, as far as efficiency is concerned.

(7) The seventh and last point is the one on which the individual drive has its greatest claim to superiority, and which has done more for the individual drive than anything else. It was soon found that where motors were directly geared to the machine a greater output was possible on account of the elimination of the slip in the belt, and the consequent driving of the work up to the limit of the cutting tool. This, of course, greatly reduces the time of the operation, and, as the cost of the time is two-thirds the total cost of the product, it is easy to see what a saving could be effected. The introduction of the new high-speed steels added still more to the necessity of positive driving, and it has been well demonstrated that where heavy cuts are to be taken the positively-geared motor will show a great saving of time over the belt drive.

Herein, also, lies the solution of the problem so confusing at present to the engineer who is trying to find out just how far he can carry the individual-motor-drive idea and make it pay. In the case of large tools, it will be seen at once that the solution is plain, and a careful consideration will show that the individual drive can be successfully used down to a point *where a belt of convenient size will have no trouble in driving the cutting tool up to its limit.* Rules which fix some particular limit to the minimum size of motor to be used or the minimum size of machine to which a motor should be attached are very misleading, as it depends entirely on what the tool is intended to do. For instance, a group of 16-inch lathes in one shop may be required to only take off a very

light chip and a group drive is all right. In another shop these lathes may have heavy work so that a motor drive will pay handsomely. There is no trouble, as a rule, in driving small drill presses up to the limit of the drill by means of group drive, and these are driven successfully in this manner; the same being true of small tools in general. At present it will not pay, outside of the advantages of better light and cleaner surroundings, to drive very small tools individually; but the writer believes that cheaper motors and properly-designed tools will make the size of tool smaller and smaller till eventually it will be the prevailing system. At present each case must be worked out on its merits along the lines suggested above.

	Group Drive.	*Individual.*
1. First cost	Considerably less.	
2. Maintenance and depreciation	Probably less.	
3. Provision for extension		Much superior.
4. Sectional operation		Much superior.
5. Flexibility as to location		Much superior.
6. Efficiency of system	Not of great consequence.	
7. Positive application of power		Much superior.

Having decided what tools to drive individually and what to group drive, the next question is the matter of motors and the methods of connecting them to the machines. Here, again, a great difference of opinion exists and much conflicting literature has been written. In order to get a clear idea of what is needed in a motor for this work it will be well to look at the requirements of the tools themselves.

Machine tools may for this purpose be classified into the following groups:

(a) Machines requiring a constant speed. In this class come punches, shears, fans for ventilating purposes, and also the shafting of group drives. The torque may vary with the demand for power.

(b) Variable-speed machines requiring maximum power at minimum speed. In this class are lathes, boring mills and most machine tools where automatic regulation is needed.

Here the cutting speeds are practically constant for a given metal, but the cuts are larger on the larger work.

(c) Variable-speed tools requiring heavy starting torque, as cranes, sheet-iron rolls, etc., where regulation of speed is by hand.

(d) Machines requiring a torque increasing with the speed, as blowers and fans which give variable blast. This class is rather unimportant and will not be discussed.

Of course there is no trouble in meeting the requirements of the constant-speed machines, but the problem of variable speed is as old as the hills. If a good mechanical speed-changing device were to be had, the problem would be easy to solve. But so far none have been produced that will answer the purpose. Many have been made that will give any speed between the limits of the mechanism, but they all depend on friction, and hence to carry the work required must in most cases be very large and cumbersome; while those that are positive in their action give only several speeds between the limits and hence are not all that is desired. Of the latter type a number are now on the market which can be used with success in many places.

When the electrical side of the problem is considered a choice of two distinct systems of distribution is presented, namely, the alternating-current, and the direct-current systems, both of which have a place under proper circumstances in this work.

It may be said at the outset that when the alternating-current system of distribution can be used it is preferable, as the wiring is smaller in a large system, the generators and motors simpler and more reliable. It has, however, its limitations, as will be seen, as far as machine-tool driving is concerned.

The alternating-current system offers two kinds of motors, the synchronous and the induction motor. The first is not self-starting and, except in a few cases, has no place in machine-tool driving. Where heavy shafts as test shafts are to be run for some length of time and provision can be made for starting, a synchronous motor is an excellent thing in con-

nection with induction motors, as it tends to steady the line and help the power factor. In small sizes, however, it is not suitable for machine-tool driving.

The induction motor is self-starting, and, like the synchronous motor, tends to run at constant speed. It is by its nature not a variable-speed machine, although it can be made so in several ways, none of which, however, have so far proved adequate to the demands of machine-tool driving. It has been successfully used on cranes and similar devices, the speed variations being obtained by putting resistance in the secondary, and variable-speed induction motors are now on the market controlled in this manner. One plant, at least, has been fitted out with induction motors, where several changes of speed were obtained by varying the frequency, with fair success. But as yet the induction motor cannot be considered as equal to the direct-current motor for variable-speed work, though considerable experimental work is now being done that may change the situation.

If the plant under consideration is to contain constant-speed machines principally, the induction motor in connection with a mechanical speed-changing device will generally prove to be the best, and where all the machinery is of constant-speed type it is much preferable. Of course local conditions may effect this, as for instance, when the power is to be bought and only direct current is available.

The direct-current system offers three kinds of motors, their combined characteristics covering much more closely the requirements of the case than do those of the alternating motor, and there is little doubt as to the greater adaptability of the system for general machine-tool driving. These motors are (1) series-wound motors; (2) compound-wound motors; (3) shunt-wound motors.

The series motor is a variable-speed motor with great starting torque. It can be controlled throughout its whole range of speed and would seem at first glance to be almost ideal for lathes and boring mills. It is, however, very uneconomical, as the control is obtained by resistance in its circuit. It also

requires an expensive controller on account of the heavy current to be handled, and must be controlled by hand, as its speed varies inversely with the load, and under light loads it will run away. It is an excellent motor for cranes, elevators, sheet-iron bending rolls, etc., and occupies a very important place in the equipment. It therefore covers the requirements of the tools under class (c).

The compound-wound motor is suitable where small variations of speed are needed coupled with a large starting torque. It will, of course, give constant speed when set for any set of conditions within its range.

The shunt motor is, in its standard form, a constant-speed motor. When set to run at a given speed it will not vary appreciably under varying load up to its capacity. It can be made to vary its speed in a number of ways, those which are most used being one of the following three:

By varying the current in the armature.

By varying the strength of the field.

By varying the voltage applied to the armature terminals.

These characteristics make the shunt-wound motor most suitable of any for the purposes of machine-tool driving, and by means of these methods of control, either singly or in combination with each other or in combination with gearing, most of such work is now accomplished.

Class of Machine.	*A. C. Motors.*	*D. C. Motors.*
Constant speed, torque varying with load.	Induction motor. Synchronous motor.	Shunt or compound-wound motor.
Variable speed, max. work at minimum speed, automatic regulation.	Induction motor with mech. speed-changing device.	Shunt-wound motor with or without change gears.
Variable speed. Heavy starting torque. Hand regulation.	Induction motor.	Series-wound motor.
Variable speed, torque increasing with speed.		Comp.-wound motor.

A discussion of the principal methods of speed control may be of interest. If the armature current in a shunt-wound motor be decreased by inserting resistance, the field remaining

constant, the speed of the motor will decrease. But when this method of control is used the motor loses one of its most valuable qualities. It will no longer run at constant speed under varying load. Besides, this method of control like that of the series-wound motor is very wasteful, and the controller must likewise be large and complicated to handle the large current which must be broken. This method, therefore, has ceased to be used to any great extent.

If the field strength of the shunt motor is varied the speed will vary accordingly, and in this method of control the bad features of the above method do not appear. The field current is small and therefore the resistance loss small and the controller simple and cheap. The motor likewise retains its good quality of steady running. The power, however, falls off, for now the commutating ability of the field has been decreased, so that less current can be passed through the armature. In order, therefore, to get a given output at higher speed with field control the motor must be larger than one built for the same output at the normal fixed speed.

To illustrate: A 4-H.P. motor at 400 R.P.M. will only give 1-H.P. at 1,600 R.P.M. with field control. It will be seen at once that in order to get a large range in this manner the motor must be very large. It will be noticed, however, that the characteristic of the motor fits the requirements of tools in class (b), and it is therefore much used for driving this class.

If the field strength is kept constant and the impressed volts at the armature terminals be varied the speed of the shunt-wound motor will vary accordingly. Theoretically this is a most excellent method of speed control, as it allows the use of a smaller motor than in the method of field control, and the efficiency of the motor at the various voltages is high. In practice, however, the number of voltages that can be supplied is limited, and therefore in its simplest form the system has the same defect as the method of controlling alternating induction motors by changing the frequency. It is usual, therefore, to make the motors large enough to have field control sufficient to reach between voltages, which makes a system

that completely covers the range between voltages and extends the range beyond the speed normal at highest voltage.

To illustrate: Suppose the range is 4 to 1, as before, and let the voltages be 60, 80, 110, 140, 190, 250, as used by the Bullock Co. in their four-wire system. Let the minimum rate at which power is required be 1 H.P., as before. Neglecting losses, this range of voltages alone would give six fixed speeds, and if, as before, the lowest is 400, the fastest would be about 1,600, or directly proportional to the voltages applied. The motor for the system would only need to be 1 H.P. at 400 R.P.M., instead of 4 at 400 R.P.M., as in the case of shunt field control. If now the motor is made large enough to stand an increase of speed by field control of about 33 per cent., it can be speeded up in that way from voltage to voltage and the whole range covered. Further, when running at 1,600 R.P.M. at 250 volts, it can still be speeded up to 2,133 R.P.M., making the total theoretical speed range 5 to 1.

Undoubtedly this system works well, but, like all the others, has its defects. It is not desirable to carry high voltage round manufacturing plants for obvious reasons, so that in order to get a large range in this manner the lowest voltage must be very low. To obtain the full output at low speed, and it has been seen that generally the greatest output is required at the lowest speed, the current must be increased; so that the expense of wire runs up rapidly for wiring the low voltages, or if the mains are kept down in size the line losses are heavy and the impressed volts drop off, the motor slowing down accordingly. Further the obtaining of only six voltages by a four-wire system introduces considerable complication, as is easily seen, besides the extra expense for controllers, wiring, and the machines for giving the various voltages. A description of the latter is beyond the scope of this article. Generally a motor generator set of some form is run from the main series of the principal generating set which splits the voltage of these mains. Thus a 250-volt circuit can be divided by

two wires from such a set into 60, 80 and 110-volt steps and the combinations of these give six voltages.

If a three-wire system, giving, say, 110 and 220 volts, is available a speed range of 4 to 1 can be obtained in the following manner: Let the data be the same as above, and then for this case the motor will be a 2-H.P. motor at 220 volts and 800 R.P.M. When running on 110 volts and full field it will develop 1 H.P. at 400 R.P.M. Since the motor is running below normal speed it can be speeded up through a considerable range and still commutate well. By this means probably 60 per cent. increase can be obtained with the ordinary motor, when the voltage must be changed to 220 and full field applied for any further increase. On the higher voltage the field can be again weakened till the speed is doubled, and at 1,600 R.P.M., as the motor is now large for the work to be done, it will commutate all right.

In order to make a close comparison with the other systems this motor should be somewhat larger, say 3 H.P. at 220 volts or 1½ H.P. at 110, so as to cover by field control the whole range from 400 to 800. In such a case, however, a further increase in speed could be made when running on 220 volts, thereby extending the range somewhat.

If it is not desired to use the excessively large motor resulting from entire field control or the complication of multivolage, a combination of field control and gearing can be used. Using the same data as before, the motor could be designed for a field control of 2 to 1 and a single set of change gears used in combination with it. Here the motor would be a 2 H.P. at 800 R.P.M., giving 1 H.P. at 1,600, and not exceeding the speed limit originally assumed. This method, which is a compromise between the other systems, has many good points. The wiring and generating system are simple, as only a single voltage is necessary, and the motor need not be excessively large for the work, as it can always be worked at the maximum range of speed which is allowable for gear connection. The voltage is always the highest permissible, hence the wiring is small, and while the multi-voltage system

gives somewhat quicker change of speed the difference in well-designed machines will not be very great.

In the writer's opinion it is a logical system and will be very widely used in machine-tool work mainly on account of its electrical simplicity. The efficiency of such a system is good, and if the gearing is properly designed the range covered by the motor alone need not be great enough to make it large and clumsy.

The table shows the relative sizes of the motors which must be used in the systems described above to cover the range from 400 to 1,600 R.P.M. and with a maximum voltage of 240. It will be seen that the motor with 2 to 1 field control and a single set of change gears is the smallest, requiring three ampères, approximately, when delivering 1 H.P., against six in the case of the multi-voltage at same speed. The figures for current used are, of course, approximate, and are for the purposes of comparison only.

To get the lower range of speed, *i. e.*, 400 R.P.M., the change gears with ratio 2 to 1 would be thrown in and the motor put on full field, when it would run at 800 R.P.M. By decreasing the field strength its speed would be raised to 800, when the gears would be thrown out and the motor again put on full field. The further increase to 1,600 would be accomplished by again weakening the field.

Motors giving successfully a range of 2 to 1 by field control are at present not classed as standard motors, although there is no difficulty in obtaining them or motors which will give a much greater range. This distinction will, however, disappear as they are more widely used, and there is no reason why motors giving such a range or greater cannot be made as a standard product if the demand is sufficient. A number of makes are now on the market which offer a much greater range than this, but at present, as shown by the table, it would not seem advisable to go far beyond 2 to 1, except, perhaps, in special cases.

Some of the special methods adopted to insure sparkless

commutation under increased speed with field control are worthy of notice.

In the Thompson-Ryan motor the armature is surrounded by a set of stationary coils called "Balancing Coils," running parallel to the armature winding and in series with them. These coils not only neutralize armature reaction and prevent its distorting effect, but also build up a commutation field independent of the shunt field. The latter can, therefore, be weakened beyond the limits of the ordinary motor and yet good commutation will result. This firm are now advertising a line of motors having a speed range of 6 to 1.

In the Stow and Story motors a hollow pole is used which has the effect of concentrating the field nearer the outside of the poles, hence the commutating field is stronger when weakened than in the ordinary form of motor. Of course, the general principles already discussed regarding the relative sizes of motors under various conditions hold good, also, for all these forms.

System.	400 R.P.M.			800 R.P.M.			1,600 R.P.M.		
	Max. H.P.	Cur'ent for H.P.	Volts.	Max. H.P.	Cur'ent for H.P.	Volts.	Max. H.P.	Cur'ent for H.P.	Volts.
4 to 1 field control.....	4	3	240	2	3	240	1	3	240
4-wire multi-voltage.....	1	12	60	2	6	120	4	3	240
3-wire multi-voltage.....	1½	6	120	3	3	240	1½	3	240
2 to 1 field control with 2 to 1 gearing.....	2	3	240	2	3	240	1	3	240

Column 1 under each speed gives maximum H.P. motor will give. Column 2 gives the ampère per H.P.

From the foregoing it is easily seen that the range of any of the above systems of speed control is somewhat limited, the four-wire multi-voltage having the widest for the same size motor. But even this is limited as here laid down to about 6 to 1 when using field control on the highest voltage. It is true that it can be extended by using either higher or lower voltages, both of which are undesirable. Now machine tools which require variable speed may have a range as high as 50 to 1. An ordinary 16-inch lathe, belt drive, would have a range of 12 or 16 to 1, and while, no doubt, many tools are

furnished with greater range than absolutely necessary, 6 or 8 to 1 being found sufficient for many purposes, at present it is easily seen that none of the systems outlined will conveniently cover such ranges. Resort must, therefore, be made in most cases to gearing to finish out the range even with multi-voltage. When the range to be covered is very great this last system has an advantage, but for most machines the range required can be covered with a field control of 2 to 1 and two sets of gears, and for the larger ranges which are not so frequent a field control of 3 to 1 can be successfully used.

Where a three-wire system is already installed the application of variable-speed drives is easily accomplished by the system outlined above. But when the case of a new plant is under discussion, careful consideration should be given to the foregoing principles, and the system selected should depend largely on the ratio of variable-speed tools to constant-speed tools. If the plant is large enough an alternating system with proper transforming devices might prove the best, and, in the writer's opinion, many large plants now equipped with direct-current distribution would be much more economically run if so provided.

FINE GUNS.

The maximum efficiency of the 12-inch gun has not yet been secured, in England at any rate. From all accounts the finest 12-inch gun in the world at present is the new model French 12-inch, which is being mounted in the *Danton* class. It is said to be equal to penetrating 12-inch K.C. at 8,000 yards. The special feature of this gun is a much heavier projectile than heretofore employed.

There are rumors of an extremely fine 11-inch Bofors gun, destined for the Swedish navy. Its main feature is said to be a fine penetration at long range. So far as we can ascertain, this is the gun with which it is proposed to arm the small *Dreadnoughts* that Sweden is credited with projecting.

THE CORROSION OF STEEL.

By ALLERTON S. CUSHMAN, Assistant Director Office of Public Roads, United States Department of Agriculture.

Iron is unique among the elements, not only on account of the ease with which it dissolves or combines with nearly all other elements, but also on account of the changes in structure and physical character which are produced by the presence of almost infinitestimal quantities of impurities. A variation of a few tenths of one per cent. in the amount and condition of the carbon content may produce such a change in the physical properties of the metal as to alter entirely its fitness for the various purposes to which it is put. A variation of a few hundredths of one per cent. of phosphorus in the specifications for certain useful forms of steel has been and still is a matter of controversy between interests representing hundreds of millions of dollars of capital and involving questions of the safeguarding of the lives and property of the public. Sulphur, silicon and manganese are among the other well known elements whose presence or condition in extremely small amounts produces important differences in the character of steel. Absolutely pure iron has but a limited use in the industries of man, and as a rule the properties which are sought are produced by the presence of other elements.

This point is emphasized in order to call your attention to the fact that, chemically speaking, structural iron or steel is not a standard substance, but varies in composition and in character.

I have frequently called attention to the fact that resistance to corrosion was one of the most variable of the many characteristics of steel. That is to say, not only do the various kinds of merchantable iron and steel differ from each other within the wide limits in their resistance to corrosive influences, but specimens from the same mill or furnace will frequently show a great difference in this respect. There are few subjects at the present time more important to the engineer and the architect than the protection of structural steel

from rapid, unsightly and dangerous corrosion. I wish to point out that there are two separate and distinct lines along which we may hope to make progress.

The first of these has to do with the understanding of the causes which promote corrosion and their elimination in the manufacture of the metal, and the second is the study of paint films or waterproof coatings which shall really protect even the most inferior metals for indefinite periods. It is only the first phase of the subject that I shall consider tonight.

The tendency to oxidation is a characteristic inherent in iron, and an absolutely unrustable iron or steel will probably be impossible of accomplishment, even in the distant future. If, however, all the steel made resisted corrosion as well as the best of it, there would be no problem, and this paper would not have been written.

I shall not take your time this evening to review the older theories which were held to account for the rusting of iron, but will call your attention to the electrochemical or electrolytic explanation, which is now coming to be generally accepted. According to modern chemical theory, all reactions which take place in water solution are attended by certain readjustments of the electrical states of reacting particles which are called ions. You are undoubtedly aware that under the atomic theories molecules of compound substances are made up of atoms which are held together by a force or forces which represent large amounts of energy. Now, some substances, when they are dissolved in water, will conduct electricity, while others will not. The first class of substances which are generally inorganic acids, alkalies and salts, we call electrolytes, while those organic bodies, such as sugar, which do not conduct electricity in solution, are non-electrolytes.

Arrhenius, a Swedish physicist, in 1887, announced the theory of electrolytic dissociation, the evidence for which can not be discussed here, but it can be said that the theory has been borne out by numerous researches, and is at the present time almost universally accepted. This theory tells us that

the molecules of electolytes, as they pass into solution in water, dissociate into ions which are simply atoms carrying, in spite of the smallness of their mass, very heavy charges of electricity. In order that no energy may be lost or gained, it follows that the dissociation must produce both positive and negative ions, which are equivalent and opposite. A rough analogy of what has taken place through dissociation is furnished by a coiled-steel spring. If we put such a spring in tension and hold it thus, without addition or subtraction of material, we have impressed potential energy upon it, which will be returned in equivalent amount when by any means the tension is relieved. Indeed, we might consider one end of the spring as positive to the other end, and that in relieving the tension the energy reappeared by the neutralization of the positive and negative potentials.

To illustrate further what is meant by the theory of solutions, let us consider the system common salt and pure water. Common salt is composed of an atom of sodium combined with an atom of chlorine, and the molecule is represented by the simple chemical formula Na Cl. When sodium chloride is brought together with water it tends to go into solution, the molecules mingling with the molecules of the water, owing to a force known as solution pressure. As an increasing number of molecules appear in solution, however, a back pressure is exerted which to a constantly increasing extent resists the entrance of more molecules. This reverse action is known as osmotic pressure and it is perfectly clear that if an excess of salt is present the end of the action will come about for any definite temperature just as soon as the osmotic pressure and the solution pressure are equal. But in addition to this the very important action takes place which has been just referred to. In passing into solution the salt dissociates into its constituent ions, which simply means that the solution forces tear apart the associated atoms, and the energy which held them together appears in a potential form as equal and opposite charges of static electricity on the ions. So that the solution of salt in water is represented by the equation:

$$Na\,Cl \longrightarrow \overset{+}{Na} + \overset{-}{Cl},$$

in which $\overset{+}{Na}$ and $\overset{-}{Cl}$ represent the constituent ions. Osmotic pressure, however, acts against the dissociation pressure just as it does against the solution pressure, so that in concentrated solutions we have a reverse action also taking place represented by the equation:

$$\overset{+}{Na} + \overset{-}{Cl} \longrightarrow Na\,Cl.$$

Chemists therefore say that the state of equilibrium for the system we are considering can be expressed by the reversible reaction:

$$Na\,Cl \rightleftharpoons \overset{+}{Na} + \overset{-}{Cl}.$$

Now, bearing these simple details of the modern theory of solution in mind we may return to the consideration of the reactions which take place when iron rusts. If a bright strip of iron is immersed in a solution of a copper salt, such as the sulphate, iron goes into solution and copper plates out on the iron. The reason for this is that the solution pressure of the iron is greater than that of the copper ions, therefore iron passes into solution, the positive static charge being transferred from the copper ions to the iron ions. This reaction is simply written:

$$Fe + \overset{+}{Cu} \,.\, \overset{-}{SO_4} = \overset{+}{Fe} \,.\, \overset{-}{SO_4} + Cu.$$

Now if we leave out the copper sulphate in this system, and immerse the strip of iron in plain water, a similar reaction takes place. It is known to chemists that even the purest water is to a slight extent dissociated, and therefore contains hydrogen ions. That is to say, while water consists mainly of molecules written H_2O, there also are present positive hydrogen ions $\overset{+}{H}$ and the equivalent negative hydroxyl ions $\overset{-}{OH}$. Hydrogen acts as a metal and has a solution pressure somewhat less than that of iron. Therefore, when iron is by any means whatever brought into contact with water it will, to a

certain extent, pass into solution by exchange with hydrogen. This reaction, upon which all forms of corrosion are primarily based, may be written :

$$Fe + 2\overset{+}{H} \,.\, \overset{-}{O}H = \overset{++}{Fe} \,.\, \overset{-}{O}H.\overset{-}{O}H + 2H.$$

It has been shown experimentally that iron cannot, at ordinary temperature, combine with oxygen unless the iron first passes into solution, and it is apparent from this that the initial cause of rusting is not oxygen, but hydrogen, bearing a static electrical charge, in other words, the hydrogen ion. Now all acids derive their character from the fact that they dissociate in solution with the production of hydrogen ions, and this is the reason why all acids stimulate the corrosion of iron. On the other hand, alkalies dissociate in solution with the production of hydroxyl ions, which, by the reverse action already explained, neutralize and remove the hydrogen ions and thus inhibit rusting.

It is well known to engineers that sulphurous acid, as well as carbonic acid, from coal smoke produces rapid destruction of steel, whereas alkaline cements, mortars and concretes will preserve steel imbedded in them so long as the reaction remains sufficiently alkaline. The only cases recorded in which steel is said to have corroded when imbedded in concrete are those where percolating water under pressure has washed away the free lime and thus removed the alkaline reaction.

We may now turn to the rôle played by oxygen in the rusting of iron. Iron is one of those elements which exists in more than one state of combination with oxygen. The least oxidized state is called ferrous, while the higher state is called ferric. Oxygen always changes ferrous to ferric compounds. Iron, having once appeared in solution in the ferrous condition by exchange with hydrogen, is at once attacked by oxygen and precipitated at the point of attack in the form of the insoluble hydrated ferric oxide which is known as rust. This statement is easily proved by experiment, for all solutions of

ferrous salts are directly oxidized or rusted by standing in the air. The rôle of oxygen is therefore secondary, but it is none the less important, for the simple reason that by precipitating the insoluble rust the iron ions are destroyed and removed from solution, thus lowering the osmotic pressure and making room for more to be formed. The scientific explanation would be that the appearance and precipitation of the solid phase (rust) lowers the osmotic pressure, thus enabling the iron, driven by its solution pressure, to pass rapidly into the ionized condition.

To sum up, then, as far as we have gone, the rusting of iron is caused, first, by the solution of the metal by exchange with hydrogen, and secondly, by the action of oxygen on the dissolved portion, both actions being accompanied by a transfer and neutralization of electric charges on the reacting atoms or ions.

The next important point is that the solution of the iron does not, as rusting proceeds, take place uniformly over the exposed surface, but on the contrary the solution is stimulated at certain nodes or points and inhibited at others. To this direct local electrolysis is due the peculiar form of corrosion known as pitting, which is almost always observed when iron and steel are deeply rusted.

The fact that iron does not tend to go into solution uniformly and evenly all over the exposed surfaces, but passes rapidly into solution at certain surface points, can only be interpreted in one way; namely, that local electrolysis is taking place.

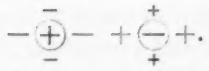
Now, applying what has already been said, it follows that as each iron ion appears in the solution a hydrogen ion must leave the system in order to maintain the equilibrium and so that no energy be lost or gained. It follows from this that hydroxl ions must be left behind as the hydrogen changes into the gaseous form and disappears, so that we should expect to find a congregation of iron ions at one pole in the electric circuit and hydroxl ions at the other. Owing to the formation,

then, of these local electric couples, the surface should be protected at the negative poles around which the alkaline hydroxl ions cluster, and attacked at the positive, where the iron is passing into solution, and being acted upon by oxygen.

Now, this action can be easily made visible as it takes place by means of a special indicator to which the writer has given the name ferroxyl. There is a certain reagent called potassium ferricyanide that forms a beautiful blue color, known as Turnbull's blue, when it comes into contact with ferrous ions. There is also an organic substance known as phenolphthalein which makes a rose-pink color with hydroxl ions. Specimens of steel immersed in a solution of these mixed substances, and stiffened with agar-agar jelly so that they cannot shake about, invariably show blue and red nodes, proving beyond all doubt the development of positive and negative nodes as corrosion proceeds.

Time will not allow of the presentation of a full discussion of the proofs that have been given to show that the corrosion of iron is always due to local electrolysis on the surface of the metal itself. The subject has been presented in detail in a bulletin recently issued by the Department of Agriculture. One of these demonstrations will, however, probably be of interest here.

When a section of rolled metal, such as sheet or plate, is immersed in water, if the electrolytic theory is correct, rusting must take place with the establishment of positive and negative spots or areas. At the positive points iron will pass into solution and be rapidly oxidized to a loose, gummy, or so-called colloidal form of ferric hydroxide which is characteristic of rust formed under these conditions. It is a well-known fact, as has been proved by experiment, that colloidal ferric hydroxide will move or migrate to the negative pole if subjected to electrolysis. We may therefore consider the possibility of two separate effects that may be produced, viz: when a positive center is surrounded by a negative area, and vice versa. These two conditions may be graphically represented by the two circles A and B:



Now, as rusting proceeds we should expect in the case of A that the ferric hydroxide would be piled up in a crater formation, while the metal is eaten out at the center. In the case of B the effect would be reversed, and while the metal would be attacked in the surrounding area the hydroxide would be piled up in a cone at the center. That this is precisely what is taking place whenever a sheet of metal rusts under water a low-power microscope very clearly shows.

The photomicrographs in which the craters and cones are clearly shown have been published in the bulletin referred to above.

If you are willing to accept the electrolytic theory of corrosion you will very naturally inquire in what respect does it point the way to an improvement in the conditions as they exist at the present time. It follows from what has been said that the more carefully lack of homogeneity and bad segregation are guarded against during the processes of manufacture the less likely is the metal to suffer from rapid corrosion. If the iron contains metallic impurities dissolved in it, such as manganese, which differ electrochemically from iron, trouble is sure to ensue if there is a lack of homogeneity in the distribution of the impurity. In the old days when iron was made more slowly and received more careful working than is possible in the present day, serious corrosion was not the important problem it has since become.

The writer has in his possession a hand-forged nail, still in good condition, which was driven in the old Masonic Hall at Richmond, Virginia, in 1807, and for a long portion of time has been freely exposed to the weather. There is a widespread opinion, which the writer shares, that the old wrought or puddled iron of thirty years ago is more resistant to corrosion than most of the modern steel.

But the interesting point is that modern steels vary so widely from each other. Here are two pieces of angle steel

which constituted two members of a signal bridge on the Boston & Maine Railroad erected in 1894. These members were only six feet apart in the structure, and the conditions of environment, exposure and care were precisely similar, and yet one is corroded to the condition of lace work while the other is hardly touched. The chemical and microscopical examinations of bright samples cut from these two specimens does not show any essential differences, both contain about 0.5 per cent. of manganese, and yet electrolysis has proceeded rapidly in one and almost not at all in the other. Does it not seem probable that the ingot, or portion of ingot, from which one of these members was rolled differed in segregation or in chemical homogeneity from the other? At all events, if all the members in this bridge structure had been as good as this best one they would still be in service instead of on the table before you. It is of the utmost importance that we should learn to control the resistance to corrosion of structural steel, and to this end we should unite to urge upon manufacturers the necessity of making special efforts in this direction.

It would follow from the electrolytic theory that in order to have the highest resistance to corrosion a metal should either be as free as possible from certain impurities or should be, by careful working and heat treatment, rendered so homogeneous as not to retain localized positive and negative nodes for a long time without change.

Manganese is an element which is almost always associated in modern metallurgy with iron and steel, owing to the fact that this element is used as a flux in the great processes used today for changing cast iron into steel. Manganese, however, increases the electrical resistance of iron, and as the percentage of this element, starting from zero, rises, the electrical resistance of the metal increases up to a certain specific maximum. Now, you will see, if the dissolving of manganese in iron raises the electrical resistance, that any changes in the equilibrium or distribution of the manganese in the

metal means that there will not be an even or homogeneous electrical conductivity throughout the mass.

If we have a metal in which the electrical conductivity for any reason varies from point to point on the surface we have the precise conditions which are necessary in order to establish the local nodes of electrolytic action on the surface which lead to rapid corrosion. It is apparent, therefore, that if we are to allow the presence in structural steel of comparatively high percentages of metallic impurities, such as manganese, we must attempt to obtain an extremely homogeneous distribution of such impurities. It is for this reason, principally, in the opinion of the writer, that the more quickly and more carelessly the metal is manufactured and rolled, the more quickly it disintegrates under corrosive influences. As has been pointed out before, there are two methods of meeting the problem: first, to keep the percentage of metallic impurities as low as possible, and secondly, to guard against segregation and imperfect chemical homogeneity in the metal. In experiments we have made looking to the manufacture of a corrugated-steel culvert for use in road building, it has been found by the author that corrugated metal, running as low as .04 manganese, has been more resistant to the corrosive test employed than the ordinary steel of the day, which usually carries about .5 per cent. of manganese. Material of this kind has not been available for a sufficient length of time to determine whether under service conditions this low-manganese metal will be longer lived, but it can safely be stated that the indications are all in its favor.

The writer has urged the manufacture of manganese-free steel for certain purposes, not because manganese is necessarily the cause of rapid corrosion, but because this impurity enables the metal to be rolled more easily and more cheaply, and in many cases permits the working in of large amounts of heterogeneous scrap. It is possible to manufacture shoddy steel as well as shoddy cloth, and though both of these materials have their legitimate uses for certain purposes, no one will claim for them high resistance to disintegrating influ-

ences. It is a hopeful sign of the times that manufacturers are beginning to pay serious attention to the manufacture of iron and steel for certain purposes which shall be to the highest possible degree rust proof.

Considerable attention has been given to the peculiarly passive condition that can be induced on the surface of iron by contact with solutions of certain oxidizing agents. Without going into the details of this phenomenon, which have already been published, I will refer briefly to the peculiar action of chromic acid and its salts. Polished specimens of steel may be kept indefinitely without suffering corrosion when immersed in a dilute solution of potassium bichromate. On first thought it would seem a paradox that a strong oxidizing agent should have the effect of preventing the oxidation of iron, and yet this is the case.

According to the theory of the writer, the oxidizing agent polarizes the surface of the iron to the condition of an oxygen electrode, so that it is immune from the attack of the hydrogen ions; thus the whole electrolytic process is checked or inhibited. A curious feature of this action is, that it is to a certain degree persistent after the metal has been removed from contact with the oxidizing solution, washed and wiped. This phase of the phenomenon requires further study, but at the present time it does not appear probable that the induced passive condition can be maintained on the surface to an extent that would make it of practical value for treating structural steel. With regard to the preservation of boiler tubes, and for certain special purposes, it is not unlikely that a practical application of these principles will be found.

In conclusion it may be said that there is reason to hope that the time is not far distant when specifications may be drawn for material that is going into service under conditions which make it particularly subject to corrosive influences. The possible added cost of such specially-resistant metal will be small in comparison to the benefits which will be derived from its use in the long run.

SHIPS.

ENGLAND.

H. M. Battleship Lord Nelson.—The latest battleships added to the British Navy are the *Lord Nelson* and the *Agamemnon*, the former built by Palmer's Shipbuilding and Iron Company, Limited, Jarrow-on-Tyne, and the latter by Messrs. William Beardmore & Co., Limited, Dalmuir. The latter has been commissioned, and is attached to the North Sea Squadron; the former has completed her trials, and will also go to the Nore. The *Lord Nelson*, is, like her consort, 410 feet long, 79½ feet beam, and has a displacement of 16,500 tons at 27 feet draught. They differ from the *Dreadnought* in their armament. Whereas the latter has ten 12-inch guns, the *Lord Nelson* has four 12-inch and ten 9.2-inch guns, and this latter combination is approved by many owing to the greater rapidity of fire of the 9.2-inch guns. Against this, however, is the lower muzzle energy and the consequent reduction of effective range. The vessel is heavily armored. The *Lord Nelson* was engined by Palmer's Company. The machinery includes twin engines of the four-cylinder triple-expansion type and Babcock & Wilcox boilers. The results of the trials, recently completed, are tabulated:

.....	Eight hours. Full power.	Thirty hours. Four-fifths power.	Thirty hours. One-fifth power.
Indicated horsepower.....	17,445.0	12,232.0	3,624.0
Coal per indicated horsepower, lbs	1.99	1.98	2.23
Steam pressure, pounds	234.0	241.0	231.0
Vacuum, inches.....	25.3	27.3	26.7
Revolutions	125.2	113.2	75.8

The designed power was 16,750 horsepower, which, it was anticipated, would give a speed of 18 knots; the actual speed was nearer 19 knots.

The British Cruiser-Speed Record for the year is held by

the *King Alfred*, which on her eight-hours' sea trial did for one hour 25.1 knots, and for the whole eight hours attained a mean of 24.8 knots. This is the mean reached by the *Drake* in her last year's record. This year the *Drake* has not made so much, 24.6 being the highest recorded.

In the eight-hours' passage trial at full power in the Second Cruiser Squadron the order was *Drake*, *Devonshire*, *Carnarvon* and *Antrim*. The *Drake* is the better steamer of these four ships by about two-thirds of a knot, being a 23-knotter against 22.33 of the others. The *Drake* did 24.3, the *Devonshire* 22.7, the other two *Devonshire*-class vessels about 22 knots.

Group of Dreadnoughts.—The Admiralty decision to build a group of *Dreadnoughts* rather than any special advance upon that type has been a good deal criticised in certain quarters, but nautically it is probably very sound. It is very doubtful whether the *Dreadnought* by herself would be any great acquisition to an ordinary fleet. Her speed would be useless among slower vessels except in exceptional circumstances, while the long range of her guns could not be greatly utilized without neutralizing the lesser ranging ships.

This being so, a squadron of *Dreadnoughts* became necessary directly the type ship proved successful. According to rumor, the solitary battleship of the 1908–1909 program will be a departure from the classical *Dreadnought* lines, and very possibly carry 13.5 guns. On the other hand, little advantage is gained from forcing the pace, and so far all nations seem contented with 12-inch or less.

Vanguard.—The keel of the *Vanguard*, a new *Dreadnought*, has been laid at the yard of Vickers, Sons & Maxim, Barrow-in-Furness. This battleship is sister ship to the *St. Vincent* and *Collingwood*, and includes all the improvements suggested by recent experiments. Her tonnage was originally 19,250, but this will be increased some hundreds of tons owing to there being several alterations in the plans since tenders were invited. She will be ten feet longer and two feet broader than the *Dreadnought*, and will be more

powerful. The builders have to deliver this battleship in two years, and she is expected to come off the stocks in November this year.

The Battleship Bellerophon.—Following the successful trials of the *Dreadnought*, three new vessels of the same type were laid down, and have now been launched. The *Bellerophon* was put into the water July 27 last from the Portsmouth dockyard; the *Temeraire* on August 23 from the dockyard at Devonport, and the *Superb* on November 7 at the Elswick yards, Newcastle-on-Tyne. These ships are somewhat larger than the *Dreadnought* in displacement, although of the same overall dimensions. They represent certain improvements over the earlier ship, prominent among which are an increase in the length of the 12-inch guns from 45 to 50 calibers, and the raising of the central turret so that its guns may be fired over the after turret, and thus increase the astern fire of the ship.

The displacement is 18,600 tons, as compared with 17,900 in the *Dreadnought*, the difference being due to an increased fullness in the form of the hull, and also to a slight increase in the draught. The weight of the hull and armor is stated to be 11,800 tons as compared with 11,100 in the case of the prototype. The launching weight of the *Bellerophon* was above 7,000 tons, and of the *Temeraire* 7,475 tons. The length is given as 490 feet between perpendiculars, with a beam of 82 feet and a draught of 26 feet 3 inches.

Propulsion is by means of four screws actuated by Parsons turbines, with a designed shaft horsepower of 23,000 and a designed speed of ship of 21 knots. With 900 tons of coal at normal draught, it is estimated that the radius of action at 12 knots would be 5,800 nautical miles. It is possible, however, to carry a total of 2,500 tons of coal and oil.

The main defensive armor consists of a belt with a maximum thickness amidships of 11 inches, decreased to 4 inches at the ends. The heavy guns are in turrets protected by 11-inch armor, while the two conning towers are armored with 11 inches (forward) and 8 inches (aft) of steel. The protect-

ive deck has a thickness on the slopes of 2¾ inches, decreased to 1¾ on the flat. Some protection has been given the ships in a cellular construction of the hull to avoid the disastrous effects which might be expected from a torpedo thrown by either a torpedo boat or a submarine vessel.

The main battery consists of ten 12-inch guns, 50 calibers long, and located in pairs in five turrets. Three of these turrets are on the center line, one being on the forecastle, one on the after deck, and one aft of amidships, and at such an elevation as to be able to fire over the turret on the after deck. The two remaining turrets are placed, one on either beam, somewhat forward of amidships, and it is said that they can direct their own fire throughout a semi-circumference, from straight ahead to straight astern. This gives a broadside of eight of these powerful weapons, a theoretical bow fire of six, and a theoretical astern fire of eight. The probable maximum bow and stern fire at sea, however, would be four and six guns, respectively. The secondary battery, which is intended for defense against the attack of torpedo vessels, consists of 4-inch guns in place of the 3-inch weapons on the *Dreadnought*. In addition, there are five submerged torpedo tubes for 18-inch torpedoes, one tube being right astern, while the others are on the broadside and bows.

The ship will be steered by two rudders, as in the case of the *Dreadnought*, and of the new battle cruisers of the *Inflexible* type, and it is said that steering gear of a new type is to be fitted. One of the many minor departures from the *Dreadnought* design is the placing of the tripod mast astern of the two funnels, instead of between the two as in the type ship. —"International Marine Engineering."

A Wonderful Floating Dock Yard.—The fitting out of His Majesty's ship *Cyclops* by Sir James Laing & Son, ship builders, Sunderland, has now been completed, and from particulars that can be obtained she is destined to be one of the most novel craft afloat. The secrets of this ship have been so jealously guarded that even the workmen of the builders have been conducted to the departments in which their work

lies, and have not been allowed to communicate with any other part of the ship. Even at meal times, if the workmen had brought their food with them they had to go ashore to eat it, all this in accordance with the carrying out of the official-secrets act. Nevertheless a few privileged persons have been allowed to see through the ship, and they all speak with wonder of what they have seen. The works on board the ship are equivalent to those of a dock yard employing 300 workmen, that being the number of artificers she will carry in addition to the crew to work the ship. H. M. S. *Cyclops* may be described as the most complete repair ship or floating dock yard in the world, and is the outcome of an experiment made some time ago when an old cruiser was converted into a repair ship at Portsmouth and named *Vulcan*. The *Cyclops* is a vessel of 11,000 tons and her dimensions are: Length, 460 feet; breadth, 55 feet; and depth, 40 feet. Ship-yard and engineering machinery are fitted up in her interior. As a matter of fact there is not a machine to be found in a ship yard or marine-engine works that is not represented in the hold of the *Cyclops*. On her lowest deck is a fully-equipped foundry and forge with cupolas where damaged parts of machinery can be replaced by new castings. Then there are carpenters', blacksmiths' and armorers' shops, fully equipped, fitting works, coppersmiths' and electricians' departments. On a higher deck is a boiler shop where boiler and ship plates can be dealt with, punching and shearing machines being there just as in a land ship yard. A powerful crane travels all around the ship to lift repairs from the holds, and on or off the warship that has come up for repairs. An electricity generating station is also included in the *Cyclops*' equipment, for by this power all the machines and cranes are worked. Ice-making plant is also carried, and as a contrast refrigerating is also represented, while on another deck is a gigantic set of condensers capable of supplying a whole fleet with fresh water. A few examples of the capabilities of the works on board may be given. If she is accompanying a fleet at sea and one of the ships loses a propeller, instead of being towed

home to a dock yard, the commander will simply signal to the *Cyclops* for a new propeller to be made and the order will be executed. The same applies to anchors, and in this connection it is amusing to see a huge anchor hanging over the bows of the *Cyclops* in correct position which on close examination proves to be made of wood. This is simply one of the complete sets of templets which the vessel carries for all sorts of castings required in the navy. In addition to having any portion of machinery renewed or repaired, vessels of the fleet, in case of the refrigerating plant breaking down, can be supplied with unlimited quantities of ice from the *Cyclops*, made on board, and in case of accidents to their condensing plant supply them with fresh water. The vessel has taken two years to fit out since she was launched. She has a speed of about 16 knots an hour, and she is believed to be the only specially-built craft of her kind in the world.—"Marine Review."

FRANCE.

Trials of French Battleships.—The four French battleships *Democratie*, *Justice*, *Liberté et Verité* which belong to the Naval Program of 1900 will shortly be added to the effective strength of the French navy. For the first time for a very long while France is about to have a fleet of similar vessels of large displacement. This is all the more remarkable because ever since sailing vessels went out it has been the custom to have a conglomeration of warships of different types to form the navy, or, as one of their own admirals has called it, a veritable "naval museum."

The four newest battleships differ from the *République* and the *Patrie* in the weight of their armament. In addition to their 305-mm. (say 12-inch) guns, these two latter vessels have only a comparatively feeble secondary armament. In consequence they could not compete on equal terms with similar vessels of other nations. In the four newer vessels the number of secondary guns has been decreased, but their caliber has been increased. Their armament consists of four 305-mm.

guns, arranged in pairs in turrets placed axially; six 194-mm. (7.76-inch) guns, in six turrets arranged hexagonally on the spar deck, three on each side; four guns of like caliber, and twenty-two 47-mm. (1.85-inch) quick-firers, which are undoubtedly of too light a character to repel the attack of modern destroyers.

As regards speed, as may be seen from the table following, the results achieved by the *Democratie* and *Justice* come very near those attained by the *République* and the *Patrie*.

The first thing which strikes one on reaching the bridge of one of these battleships is the absence of the encumbrances which it has been customary to find on all the vessels built previously to the 1900 program. The decks, both fore and aft, have been kept wonderfully free, and this permits of an unrestricted use of the 305-mm. guns, and as well as of those of 194-mm. bore. It is, however, to be noticed that boat stagings are placed directly above certain turrets, and it is pretty certain that after one or two shots all this ironwork would be wrecked, and by falling down put the guns out of action. On getting below decks it is also striking not to find the hamper which is so commonly met with in French warships. As a matter of fact there are unusual facilities for getting about and for carrying out maneuvers. The transverse armored bulkheads, however, are only provided with two openings, one at each side, and these openings only permit of the passage of one man at a time.

The conning tower is of large size in the vessels of this type. There is a good view of the horizon, but sufficient precautions do not appear to have been taken to prevent splinters entering the windows. The approach to the tower seems to be better protected than in other types.

The armored tubes which protect the bases of the turrets of the 194-mm. guns and serve for raising the ammunition from the upper armored deck to the spar deck, do not appear to be sufficiently strong to withstand the attack of an enemy, who could easily hit them, as they are not behind any protective armoring. The funnels, too, have no protection between

decks, and if a well-directed shot traversing the spar deck were to wreck one of the funnels life would be impossible in a not inconsiderable part of the ship, while, of course, the evaporative power of the boilers would be reduced, and, as a consequence, the speed of the vessel also. It is difficult to understand why such important parts should have been left unprotected in this manner.

The quarters of the admiral and commandant, which are placed aft, are luxuriously arranged, but are decorated with very inflammable materials. The metal bulkheads are covered with pitch pine 2 cm. thick, which has not been made non-inflammable, and which is covered with embossed linoleum. This combination would be excellent for feeding a conflagration, and as the quarters are not protected with armor, they could easily be set alight by the enemies' fire. Moreover, in the various apartments there is a much larger quantity of woodwork in the furniture, fittings, &c., than is met with in similar British or German vessels. These quarters are situated just aft of the aft 305-gun turret, and if a fire were to occur in them it would greatly hinder the manipulation of the guns in this turret.

Coming now to mechanical arrangements, there is, apparently, much to be desired. First of all, there is the rudder, which is only worked electrically. This is provided with a mass of controlling apparatus, registers, &c., which will give an angle to half a degree, perhaps, and which will work at three speeds; but, apparently, the least little thing puts all the arrangements out of gear, and the system is so thoroughly complicated that it takes a long time to put it ship-shape again. Nothing may, of course, go wrong in times of peace, but serious trouble might arise if anything happened to the rudder-controlling mechanism while the vessel was in action; and this part of the equipment has been severely criticised by some French naval experts.

The three main engines are in one compartment in the center portion of the vessel, and space has had to be so much economized that it is difficult for a man to get round and

between them. Consequently, supervision, oiling, upkeep, and, much more, repairs or the replacing of any part, can only be carried out with considerable difficulty. Further than this, in order to take the fullest advantage of the latest developments in machinery, a whole host of controlling and regulating devices, of counters and registering arrangements, has been provided, which, though they may permit of easier navigation during maneuvers, and of brilliant evolutions, render the working of the machinery all the more difficult when the vessel is in action, and, it is thought, might consequently cause her to be totally lost. The descent to the engine room is typical. It is by means of a single ladder, which only allows of the passage of one man at a time, and in case of accident, whether during trials or during maneuvers, it would be impossible to aid quickly those who might be down below. In spite of these defects, to which we may say our attention has been called by one having a large knowledge of French warships, two out of the four of these vessels —that is to say, the *Democratie* and the *Justice*, which are the first of the four to undergo their trials—have done some excellent work as regards speed, as will be seen from the table compiled from data of their official trials.

The speed of *La Justice* under natural draft with all boilers at work during her twenty-four hours' trial was only six hundredths of a knot below the contract speed with forced draft, which is undoubtedly a remarkable performance.

The battleship *Liberté* has also recently concluded her acceptance trials. In these a comparison was made between her and the battleship *La Justice.* The members of a commission which had been appointed to carry out the trials first of all went on board *La Justice* at Toulon to make a three-hours' forced-draft trial, with only three-quarters of the boilers under steam. Eighteen thousand five hundred indicated horsepower was easily maintained, though it will be remembered that the contract requirements were only 17,500. The coal consumption during this trial worked out at 860 grammes, which is equal to 1.895 pounds per horsepower hour. On their return

OFFICIAL TRIALS OF THE BATTLESHIPS *LA DEMOCRATIE* AND *LA JUSTICE.*

	Contract requirements.	Results obtained with *La Democratie.*	Results obtained with *La Justice.*
Three Hours' Trial with all Boilers and Forced Draft.			
Type of boiler	...	Belleville	Niclausse
Number of boilers under steam	...	22	24
Grate area at work, sq. m.	...	124	128
Indicated horsepower	17,500	19,190	18,848
Consumption of coal per I.H.P., kg	...	...	0.827
Consumption of coal per sq. m. of grate area, kg	120	120	117
Average speed, knots	18	19.44	19.43
Twenty-four Hours' Trial with all Boilers and Natural Draft.			
Number of boilers under steam	...	22	24
Grate area at work, sq. m.	...	124	128
Indicated horsepower	10,500	11,472	11,630
Consumption of coal per I.H.P., kg	0.80	0.673	0.693
Consumption of coal per sq. m. of grate area, kg	...	...	73
Average speed, knots	...	17.39	17.94
Consumption Trial at Low Speed.			
Grate area at work, sq. m.	...	26.25	25.82
Indicated horsepower	2,200	2,584	2,541
Consumption of coal per I.H.P., kg	0.600	0.586	...
Consumption of coal per sq. m. of grate area, kg	...	...	75
Average speed, knots	...	7.5	7.8

to Toulon the Commissioners went on board *La Liberté* for a four-days' cruise. First of all there was a 62-hours' trial, with all the boilers at work under natural draft. A speed of 17 knots was maintained without difficulty. Following this was to have been a 24-hours' run with only twelve boilers under steam, burning 120 kilos per square meter of grate area, which is equivalent to 24.57 pounds per square foot. This run was satisfactorily commenced, but the vessel encountered such extremely severe weather in the Gulf of Lyons that the speed had to be reduced, as the stoking could not be carried on in such a manner as to maintain the required coal

consumption, which, as a fact, fell off to 80 kilos per square meter. Under these conditions the vessel returned to Toulon without any accident or incident. The return journey occupied 28 hours.

The following table gives the results of the official trials of the *Liberté*.

OFFICIAL TRIALS OF THE BATTLESHIP *LA LIBERTÉ*.

	Contract requirements.	Results of the trials.
Trial with All Boilers at Work under Forced Draft.		
Type of boilers	Belleville	
Number of boilers under steam	22	22
Power developed, I.H.P.	17,500.0	20,563.0
Consumption of coal per sq. m. of grate area, kg.,	120.0	117.0
Average speed, knots	17.0	19.31
Twenty-four Hours' Trial with All Boilers at Work Under Natural Draft.		
Number of boilers under steam	22	22
Power developed, I.H.P.	10,500.0	11,624.0
Consumption of coal per H.P. hour, kg	0.750	0.634
Average speed, knots	...	17.37
Consumption Trial at Low Speed.		
Number of boilers under steam	5	5
Consumption of coal per H.P. hour allowed, kg	0.700	...
Actual consumption per H.P. hour, kg	...	0.604

Number of engines, 3.

Diameters of cylinders, 860 mm. (33.86 inches), 1,250 mm. (49.21 inches), and two of 1,400 mm. (55.1 inches).

Stroke of all pistons, 1,130 mm. (44.49 inches).

Pressure of steam at stop valves, 16 kilos. per sq. cm. = about 227.5 pounds per square inch.

All the vessels which have been built since February, 1903, have to make their full-power trials in the following manner: A trial of ten hours' duration, with all the boilers under steam and with forced draft. Then a trial of three hours' duration, with only three-quarters of the boilers under steam. Under these circumstances the speed is to be the same as in the first trial. This arrangement is intended to imitate war condi-

tions, in which 25 per cent. of the boilers may be put out of action. The first large vessel to be tested under this new rule on coming from the hands of her constructors will be the *Ernest Renan*, of 36,000 indicated horsepower, which will probably undergo her trials at the end of May, this year.—"The Engineer."

GERMANY.

Trials of the German Battleship Pommern.—This ship, which was launched in December, 1905, is one of the *Deutschland* type, with a displacement of 13,000 tons, and designed for a speed of 18 knots, with 16,000 horsepower applied to three screws. The length between perpendiculars is 398 feet 6 inches, with a beam of 72 feet 10 inches, and a draught of 25 feet. Provision is made for the carrying of 700 tons of coal at a normal displacement, which may be increased to 1,600 tons with bunkers full, besides which 200 tons of oil may be carried.

The military features include a battery of four 40-caliber 11-inch guns mounted in pairs in turrets on the center line, forward and aft; fourtern 40-caliber 6.7-inch rapid-firing guns; twenty-two 3.4-inch guns; fourteen 1-pounders; four machine guns, and six submerged torpedo tubes. The armor belt has a maximum thickness at the waterline of 9.45 inches, decreased to 3.94 inches at bow and stern. The heavy guns are protected by 11 inches of armor, and the lighter primary guns by armor from 5.9 to 7.87 inches in thickness.

In a 6-hour forced-draft trial September 13 a speed of about nineteen knots was obtained, the horsepower being 18,697, with 118 revolutions per minute, an air pressure of 0.9 inch, and a coal consumption per indicated horsepower per hour of 1.61 pounds. The next day a maximum speed of 19.26 knots was reached at 122.8 revolutions per minute, and 20,348 horsepower (Admiralty coefficient 194). On September 17 a 24-hour trial was run, in which the center screw was allowed to run idle, propulsion being by means of the two side screws. With 3,464 horsepower the speed was 10.88

knots (Admiralty coefficient 205.5), while the coal consumption was 1.59 pounds per horsepower-hour.—"International Marine Engineering."

The Ersatz Baiern will be launched in February at Wilhelmshaven. She will be pushed on at record speed in order to test the design. Some special interest attaches to this ship on account of the vigorous denials of her being built made by some of our contemporaries seeking excuses for our reduced naval shipbuilding program. The slip at Wilhelmshaven was destroyed last spring, so that she could not be laid down, and right on into the summer she was not laid down. Quite a number of people began to regard her as a myth. She appears, however, to be a very solid one.

She will probably be ready for her trials at the end of this year, with the acceleration of building. In any case she will be to all intents and purposes ready for sea by March, 1909, the date always stated in Germany for her completion. So the delays caused to the German program by the *Dreadnought* do not seem to be over and above serious.

German estimates for 1908 provide for nine new battleships, of which two are of 13,000 tons each, and are practically ready; four armored cruisers, two of which are practically complete; six small cruisers, twenty-four destroyers and seven submarines. Seven battleships are now under construction, or to be laid down in 1908. They belong to the *Dreadnought* type, with a displacement of at least 18,500 tons each. Taking a new Navy Bill as a basis for calculation, Germany at the end of 1914 will have afloat sixteen new battleships of the *Dreadnought* type and five cruisers of the *Invincible* type, supported by ten battleships of 13,200 tons, none of them over twelve years old, and two armored cruisers, of 11,600 tons, just eight years old.

Submarines.—The construction of submarine boats has recently been taken up by German shipbuilders, and, after a series of trials on a small model boat, the Germania shipyard at Kiel have just completed a large submarine of 240 tons. The main dimensions of this vessel are: Length over all,

137.5 feet; maximum width across frames, 11.7 feet; draught of boat when emerged, 7.8 feet. An electric motor and gas engine, each with an output of 200 I.H.P., are fitted to each of the two propeller shafts, the propeller being adjusted from the inside of the vessel. The electric motors are designed for propulsion below water, and receive current from an accumulator battery installed amidships. The battery is sufficient to drive the boat below water for fully three hours at its maximum speed of 9 knots. When on the surface the gas engines are preferably to be used. The fuel is carried in tanks, arranged outside of the boat (according to patents of the Germania shipyards) thus guarding against explosion. The store carried by the submarine enables the latter to cover a distance of 1,000 knots at her maximum speed of 11 knots on the surface.

The motors can obviously be used also for propulsion above water, while both types of motor can also be used simultaneously for the propulsion of the vessel.

The submersion and emersion of the boat is effected by filling and discharging the ballast tanks arranged inside, as well as by the aid of two pairs of horizontal rudders. The maximum admissible depth of submersion has been fixed at about 120 feet. Only five minutes are required to prepare for submerging the boat.

Special care has been bestowed on ventilation, which is secured by an electrically-operated ventilator, which, as long as the boat is above water, will constantly supply all the rooms with fresh air. When submerged, the vitiated air is passed through a cleaning tank, after which it returns towards the various compartments of the boat. With a crew of 10 men, the vessel is able to move under water for periods up to 24 hours.

The armored conning tower arranged in the center of the boat and enclosing all necessary instruments, such as viewing apparatus, manometers, rudders and telephones, is large enough readily to accommodate the commander and the pilot. Two periscopes have been provided, which, both in a vertical

and horizontal direction, cover a field of 50 degrees. The length of these inclosing telescopic tubes has been chosen with a view to allow the boat to travel at a depth sufficient to warrant it against gun fire, while still enabling it to cover the whole of the horizon.

The armament of the submarine comprises an 18-inch bow torpedo-launching tube. One of the three large-sized torpedoes carried by the vessel is contained in the tube, while the two remaining ones are arranged in watertight reservoirs.

Trial runs performed in Eckernförde Bay, both in the emerged and submerged condition, have demonstrated the satisfactory sea-going qualities of the submarine.—"Scientific American."

The launching of the Nassau.—The first of the great German all-big-gun ships, the *Nassau*, was successfully launched March 7, 1908, at the Imperial Dockyard at Wilhelmshaven. Not only in armament, but in arrangement of turrets and guns, the *Nassau* is to be the most powerful ship that has yet taken the water in any part of the world. The German government is maintaining the greatest secrecy on this point, but there is now not the least doubt—unless reliable sources of information are entirely misinformed—that the *Nassau* will have a stronger all-big-gun battery than either the improved British *Dreadnoughts* of the *St. Vincent* class, the French *Dantons*, the American *Delawares*, the Japanese *Akis*, or even the proposed Italian ironclads.

American naval students will, perhaps, find some difficulty in identifying the *Nassau* in their "Brassey" or "Jane," or even in the official German Navy List. It is the *Ersatz Bayern*, about which so much has been said and written. *Ersatz Bayern* was not intended as the name of the ship when those two words were incorporated into the Navy List. Perhaps the nearest English equivalent for the German word "Ersatz" is "substitute." *Ersatz Bayern* merely means "Substitute for the *Bayern*." Germany has a continuous building policy. Until the adoption of the present Naval Estimates, the age limit of German battleships was twenty-five years. This has

been reduced to twenty years. Every time a German battleship attains that age another is to be laid down in her place. There is already an old *Bayern*, and the *Nassau* is the ship that takes the place of this obsolete vessel. Until a name had been chosen for the substitute for the *Bayern* this new vessel had to be designated some way in official naval nomenclature, and *Ersatz Bayern* was regarded as a better temporary method of identification than the use of "A" or "B" in speaking of the ship. But, as soon as the new vessel was officially christened she shook off her old designation, and from now on she will be known as the *Nassau*. What are now denominated as the *Ersatz Sachsen*, the *Ersatz Baden* and the *Ersatz Wurtemburg*, which are to supplant the old *Sachsen*, *Baden* and *Wurtemburg*, will also receive other names when christened.

The *Nassau* was christened by the Grand Duchess of Baden, in the presence of a great gathering of officials, headed by the Emperor, Prince Henry of Prussia, Prince Rupprecht of Bavaria and Prince Henry of the Netherlands. The keel of the *Nassau* was laid in July, 1906, and she is the pioneer of the four ships of this class, representing the Fatherland's reply to the British *Dreadnought*. The building of the *Nassau* has taken considerably longer than usual. This fact is attributable partly to the burning of the building slip at Wilhelmshaven, but principally to the entirely novel design. Moreover, when the vessel left the stocks she was in a very advanced condition, and it is expected that the summer of 1909 will see her in commission. The work will be pushed rapidly, and she will be ready substantially at the date when Germany first contemplated having this vessel take the sea, in spite of the vigorous denials that were for a long while made as to the actual construction of the ship.

Nothing but steel has been used in the construction of the *Nassau*. The reciprocating engines are in three sections, and there are triple screws. A speed of 19 knots is hoped for by the Government. Her armor will be extraordinarily complete, and it is a noticeable fact that the belt, 12 inches thick

amidships, will extend five or six feet clear above the water-line. From this it would appear that the German Admiralty has not been oblivious to the lessons of the conflict in the Far East, which clearly demonstrated the danger of a belt submerged at anything over normal displacement.

Reams have been written and all sorts of theories advanced in respect to the probable armament of the *Nassau*, but it is now practically certain that she will carry sixteen 11-inch guns of 50 caliber besides a large number of rapid-fire weapons for repelling torpedo attack. It is understood that the main battery will be arranged in eight double turrets, one forward and one aft, each flanked to port and starboard by two others, the remaining two turrets being placed amidships on an axial line with those at the bow and stern. This disposition will allow of twelve guns being brought to bear on either broadside, and six ahead or astern.

It is quite possible, however, that a heavier stern fire may be realized by elevating one of the turrets amidships, so as to enable its two guns to fire over the stern turret and thus bringing eight guns to bear.

An alternative arrangement has been mentioned, whereby the two middle turrets would be placed to port and starboard respectively, but farther from the axial line than the forward flanking turrets. This would mean a broadside fire of only ten guns, though ten could be brought into action ahead and ten astern. The adoption of the first arrangement is, however, almost certain.

The total cost of the *Nassau* is approximated at $9,187,500. Of this $5,568,000 goes for the actual construction, armor and equipment; $3,375,000 for the guns; and $247,000 for the torpedo armament. In this sum are included the expenses which will be incurred in connection with the trial trips. The battleship will carry eight hundred and sixty men, or one hundred and thirty more than any previous German warship, and there will be twenty-seven executive and engineer officers. The *Nassau* having now been launched, the building slip will be immediately prepared for one of the

battleships of this year's program—the *Ersatz Oldenburg*, the *Ersatz Siegfried* or the *Ersatz Beowulf*.

The huge armored cruiser designated "*E*," in course of construction at the Keil Imperial Dockyard, will take the water on April 11. Originally set for the end of March, the launching has been postponed until the former date, owing to delay in the delivery of several large castings. Very few details of an authentic character are known about this vessel, but it is believed that she will embody most of the essential details of the British *Invincible* type except that her armament will consist of twelve 11-inch guns. A speed of 25 knots an hour is projected, and turbines have been mentioned in connection with this cruiser; but in view of the German Government's known coyness in regard to this method of propulsion, it is likely that reciprocating machinery will be installed.

It is instructive to note that the recent speed trials of the new German warships have shown a considerable increase over the contract speeds. The battleship *Pommern*, 13,040 tons, over a measured mile reached a speed of 19.21 knots, whereas the contract speed was 18 knots an hour. The turbine protected cruiser *Stettin* has also exceeded her contract speed; while the armored cruiser *Gneisenau* did 23.8 knots on her trial trip, an increase of 1.3 knots over the contract.

The armored cruiser *Scharnhorst*, which ran ashore near Keil on January 16, while engaged in target practice, left the dockyard hands again a fortnight ago, apparently in as good condition as originally. The repairs have been executed with commendable promptitude, having extended over barely five weeks, which, in view of the serious damage she sustained, —a hole 90 feet long was torn in the hull,—is something of a record Pessimistic reports circulated in the national and, foreign press after the accident, and it was generally believed that the cruiser would be off the active list for at least a year. —"The Navy."

GREECE.

Torpedo-boat Destroyer for the Greek Navy.—The last of the four torpedo-boat destroyers built for the Royal Hellenic Government by Messrs. Yarrow & Co., Limited, of Poplar and Glasgow, has now completed her trials, and will be handed over very shortly to the representatives of the Government. These vessels are of the following dimensions: Length, 220 feet; breadth, 20½ feet; depth amidships, 12 feet 4 inches; displacement, 350 tons; indicated horsepower, 6,000. Contract speed, 31 knots, when carrying a load of 60 tons. The main machinery consists of two sets of four-cylinder triple-expansion engines, driving two shafts, steam being supplied by four Yarrow straight-tube boilers.

The hull is built throughout of high-tensile steel. The armament consists of two 76-millimeter and four 57-millimeter Hotchkiss quick-firing guns and two torpedo tubes. It is worthy of note that when these vessels were proposed, no vessel of a similar type and displacement was armed with such heavy artillery.

The bridge and platforms extend from the conning tower to well abaft the foremost boiler-room bulkhead, the uptake from the forward boiler being carried horizontally for some distance to enable this to be done. It is most important, as all navigators know, for the steering position to be as far removed from the bow as possible, and by means of the device adopted by Messrs. Yarrow & Co. of conducting the gases from the forward boiler for a certain distance in a horizontal direction before joining the funnel, this can be carried out.

There are four ammunition hoists by Megy for the rapid supply of ammunition to the guns, these hoists being in direct communication with the magazines and shell rooms by means of trunks to the upper deck, that for the forward 76-millimeter gun being continued to the height of the gun platform. Valves are fitted to the ship's side below water to admit of rapidly flooding the magazines and shell rooms in case of fire.

Efficient means for rapidly changing the air in the maga-

zines is provided by an installation of Sturtevant electrically-driven fans, each of which is capable of dealing with about 250 cubic meters of air per hour.

In the last two vessels provision is made for five separate cabins for the officers, four of these opening out of the ward-room.

Each vessel has a complete installation for electric lighting, the whole of the navigating instruments being electrically illuminated. A searchlight projector is also fitted abaft the bridge, and the crew spaces and officers' apartments are very efficiently ventilated by means of electric fans fitted in mush-room ventilators.

The speed obtained on the full-power trials of the *Lonki*, one of the vessels, with a load of 60 tons, was 32.535 knots, during a continuous run of three hours duration, the radius of action at a speed of 14 knots being about 3,970 miles. Progressive trials were carried out to determine the speeds obtainable under deep-load conditions, the displacement varying from 405 tons to 387 tons, the load varying from 119 tons to 101.5 tons. We understand that the results of the whole of these trials have given the greatest satisfaction to the Greek authorities.

The construction of these vessels has been under the superintendence of Captain Hepites, the Chief of the Greek Naval Commission, and Mr. Leondopoulos, resident inspector, and to these gentlemen a great deal of the credit is due for the success of these four destroyers. The names of the vessels are *Thyella*, *Nafkratoussa*, *Lonki* and *Sfendoni*, which names, when translated into English, mean *Squall*, *Champion*, *Spear* and *Sling*.

Considering the speed obtained with these Greek destroyers, and that each vessel cost about one-third of the recently-constructed 33-knot destroyers for the British government, many naval authorities are of opinion that the small additional speed obtained in the latter type is not worth the enormous additional cost.

ITALY.

Italian Armored Cruiser Pisa.—On September 15 there was successfully launched from the shipyard of Orlando Brothers & Company, Livorno, Italy, the first of four first-class armored cruisers building for the Italian navy. The ship has the following dimensions:

	Meters.	Feet.
Length over all	140.5	461
between perpendiculars	130.	427
Extreme beam	21.06	69
Depth	12.15	39.9
Mean draught	7.18	23.6
Maximum draught	7.43	24.4
Metacentric height	1.2	3.94
Normal displacement, in tons		10,118

This ship is propelled by twin screws actuated by triple-expansion engines, with a designed horsepower of 19,000 under forced draft and at 132 revolutions per minute. This is expected to give a speed of 22.5 knots, with a corresponding speed of 20 knots at 15,200 horsepower and natural draft. Steam is supplied by twenty-two water-tube boilers of the Belleville type, fitted with economizers.

There is a complete armor belt running from stem to stern, with a width of 7 feet 3 inches, of which 4 feet 11 inches is below the waterline. The maximum thickness is 7.87 inches, decreased to 3.16 inches at stem and stern. The protective deck has a thickness of 1 inch.

The battery is an extremely powerful one, including four 10-inch guns, 45 calibers long, mounted in pairs in turrets forward and aft, with an arc of fire of 260 degrees, half each side of the center line. The height of these muzzles above the water plane is 24 feet 3 inches. There are eight 7.5-inch guns, 45 calibers long, in pairs in four turrets at the corners of the superstructure. These have an altitude above the water of 22 feet 2 inches. They have a range of fire of 160 degrees, of which 90 degrees comprehends the arc between the fore-and-aft line and the beam for the various guns. The secondary battery includes sixteen 3-inch guns, eight 3-

pounders and four Maxims. There are three 18-inch torpedo tubes, all submerged, two being located just aft of the ram, while the other one is just above the rudder. All of the artillery is of the latest Vickers type, and was made in Barrow-in-Furness.

These ships are such an advance over anything else of the same size and type yet laid down that a comparison with some of the efforts of other powers will doubtless be interesting. With this idea in view we will compare them with the *Charleston* class of the United States navy, the *Cornwall* class of the British navy, the *Tokiwa* class of the Japanese navy and the *Marseillaise* class of the French navy. These ships are all near enough of a size to make a comparison worth while.

	Pisa.	*Charleston.*	*Cornwall.*	*Tokiwa.*	*Marseillaise.*
Displacement, in tons.....	10,118	9,700	9,800	9,750	9,856
Horsepower.....	19,000	27,200	22,700	20,550	21,800
Speed, in knots.....	22.5	22.04	23.69	23.09	21.64
Admiralty constant.....	281	179	268	274	214
Main battery, inches.....	Four 10 Eight 7.5	Fourteen 6	Fourteen 6	Four 8 Fourteen 6	Two 7.6 Eight 6.4 Six 3.9
Broadside, in pounds.....	2,800	800	900	1,700	822

The splendid propulsive results achieved with the *Cornwall* and *Tokiwa* will in all probability be equaled or surpassed by the *Pisa*, such is the extremely high character of Italian design from this point of view. In comparison, the *Charleston's* performance is truly pitiable, and her broadside is the weakest of the five, being less than 30 per cent. as powerful as that of the *Pisa*, and at long ranges much less even than that small percentage.

JAPAN.

Mikasa.—According to a recent photograph of the *Mikasa*—or what purports to be a recent photograph—this ship remains exactly as she did at Tsushima. The photograph is certainly fairly recent, as no guns are on board, so it was taken after her salvage. The upper-deck 6-inch casemates remain as before—turrets to carry 10-inch guns are conspicuous by their absence, and we begin to suspect more than ever that the four 10-inch

added to her armament was a proposal rather than much else. We do not see how the extra weight could be managed. If it be attempted, we fancy that it will be no more successful than our increase of armament to the *Centurions*. These ships were never very fit for fighting, but they steamed splendidly. After reconstructions they were still unfit for modern battle, and also unable to steam. No reconstruction involving additional weights has ever succeeded yet, nor is any ever likely to. The original designer, we may be sure, put into armor and armament all the weight that he could. Since then guns and armor may have improved much, and ways of building ships to carry a greater percentage of these things may have been elaborated, but a ton still weighs a ton. The talented but much-criticised gentlemen who design battleships may not always hit upon an absolute best, but they certainly do not leave neglected chances to carry several hundred tons extra. Had the *Mikasa* been safely able to carry the weight of four extra 10-inch guns and mountings and armor—a trifle of from anything between 500 and 1,000 tons—she would have steamed out of Vickers, Maxim's yard with that weight used up to the last ounce.

RUSSIA.

Admiral Makaroff.—The Russian armored cruiser *Admiral Makaroff*, built by the Forges et Chantiers de la Mediterranée at La Seyne, Toulon, made 22.55 knots on her full-power trials—that is, 1.55 knots over the contract speed. She is a sister to the famous *Bayan* and differs from her only in having a solitary mast, placed between the funnels. A single mast is the regulation for all Russian armored cruisers now. Both the *Rossia* and the *Gromoboi*, which used to have three, are now reduced to a solitary mast.

Russia's Naval Losses.—The Russian navy lost in the recent war with Japan a total of fifty-six vessels, with a gross displacement of 249,000 tons, to which must be added auxiliary vessels, with a displacement of 21,000 tons. The addi-

tion of ships ready and building up to January 1 represents 145,000 tons, and the number of vessels 159. Of these 109 are torpedo craft, displacing 35,650 tons, 69 of them destroyers and sea-going torpedo boats, 10 of them small boats and 30 submarine boats. In addition are gunboats, mining vessels, auxiliary vessels, to the number of 36. The present strength of the Russian navy gives a total displacement for battleships of 161,000 tons; for cruisers, 126,000 tons; for torpedo craft, 54,000 tons; and for special, old and auxiliary ships, 253,000 tons. For the manning of the ships 57,000 men will be required, but the present strength is 47,000.

TURKEY.

New Coast-Guard Boats for Turkey.—A scout and five gunboats for the Turkish government have recently been completed at the Chantiers de la Loire. These steamers are designed for coast-guard work, and for the suppression of piracy and smuggling and the settlement of various disputes along the Turkish Coast in the Red Sea and the Persian Gulf. The scout has been named *Marmaris*, while the first of the gunboats has been called *Seddlibaschir*. These two types of vessels are quite different from each other and are not at all in line with present up-to-date practice of the larger naval powers. For their own purpose, however, they will doubtless prove satisfactory.

The *Marmaris* has an armament including four 9-pounder and two 1-pounder guns and one 18-inch torpedo tube. She has a crew of twelve officers and fifty-four men. The gunboats are arranged for three 3-pounder and two 1-pounder guns with one torpedo tube, and are manned by nine officers and thirty-eight men.

The general dimensions of the two types are as follows:

	Marmaris.	Gunboat.
Total length, feet	172	154
Extreme beam, feet and inches	24-07	...
Depth, feet and inches	13-09	11
Draught, feet and inches	11-10	7-11
Displacement, in tons	422	309

	Marmaris.	Gunboat.
Indicated horsepower	950	480
Speed, in knots	14.81	12.45
Radius of action, miles	2,000	1,200
Steam pressure, pounds	199	199
Scotch boilers	2	1
Sail area, in square feet	5,160	2,205

MISCELLANEOUS.

Trials of Lightship Number 88.—This ship has a length over all of 135 feet 9 inches, a length on the waterline of 112 feet 11 inches, a molded beam of 27 feet and a mean draught on trial of 12 feet 1 inch. The trial took place in the Delaware river November 22, 1907, and the displacement (fresh water) was 576 tons. The block coefficient was 0.572, and the wetted surface 4,749 square feet.

There is one compound engine, driving a solid four-bladed propeller. The engine has cylinders 16 and 31 inches in diameter, with a stroke of 24 inches, cutting off in the high-pressure at 66 per cent. The diameter of piston rod is $3\frac{1}{2}$ inches. The cooling area of the surface condenser is 1,160 square feet. The propeller has a diameter of 7 feet 9 inches, a pitch of 10 feet and a pitch ratio of 1.29. The developed area is 2,328 square inches and the projected area 1,840 square inches. The ratio of projected to disk area is 0.271.

Steam is furnished by two boilers exhausting into a single stack 4 feet in diameter and 45 feet high above the grate. These boilers are of the gunboat type, working under natural draft, and have a diameter of 9 feet 3 inches and a length of 16 feet $3\frac{3}{8}$ inches. The working pressure is 100 pounds per square inch. The total heating surface is 2,874 square feet, with a grate area of 73.2 square feet, giving a ratio of 39.26 to 1.

Two sets of runs were made, one set being over the measured mile (5,280 feet), while the other was a 6-hour continuous trial at full power. The measured-mile trials consisted of three runs in each direction, in order to determine the revolutions required for a speed of 10 knots. The mean of all the runs showed a speed of 9.98 knots with 125.7 revolutions per

minute, and a slip of 19.2 per cent. During the 6-hour trial the maximum horsepower observed was 394, the mean having been 320 horsepower, 119.9 revolutions per minute and a vacuum of 26.66 inches. The mean steam pressure in the boilers was 98.6 pounds per square inch.

	High-Pressure.				Low-Pressure.		
Standardization Run.	Top.		Bottom.		Top.		Bottom.
R.P.M.	...	...	...	126	...	...	...
Vacuum	...	...	...	26.5	...	...	...
I.H.P.	...	...	...	360	...	...	...
I.H.P.	...	206	...	...	...	154	...
Steam pressure	...	97	...	...	...	*6.25	...
Mean effective pressure	71.24	...	66.28	...	13.29	...	13.68
Mean reduced pressure	...	...	...	31.42	...	...	...
Six-Hour Trial.							
R.P.M.	...	...	...	126.5	...	...	...
Vacuum	...	...	...	26.7	...	...	...
I.H.P.	...	...	...	359	...	...	...
I.H.P.	...	204	...	...	...	165	...
Steam pressure	...	96	...	...	...	*6.25	...
Mean effective pressure	69.42	...	66.11	...	13.67	...	13.36
Mean reduced pressure	...	...	...	31.21	...	...	...
Linked Up ¾.							
R.P.M.	...	...	...	122.5	...	...	...
Vacuum	...	...	...	26.8	...	...	...
I.H.P.	...	...	...	329	...	...	...
I.H.P.	...	193	...	...	...	136	..
Steam pressure	...	95	...	...	...	*4	...
Mean effective pressure	68.12	...	64.3	...	12.62	...	11.89
Mean reduced pressure	...	...	...	29.55	...	...	...
Linked Up ½.							
R.P.M.	...	...	...	118	...	...	...
Vacuum	...	...	...	26.8	...	...	...
I.H.P.	...	...	...	298	. .	...	...
I.H.P.	...	175	...	...	...	123	...
Steam pressure	...	97	...	...	...	*2	...
Mean effective pressure	62.28	...	59.5	...	11.81	...	11.12
Mean reduced pressure	...	...	...	27.77	...	...	...

Observations of the auxiliary machinery showed a mean revolution per minute for the circulating pump of 196; for the air pump, 33; for the feed pump, 18.6. The temperature

* Receiver pressure.

on deck was 55 degrees F., with the following observed temperatures below: Engine room, 80; injection water, 41.9; outboard discharge, 86.6; hotwell, 102.6; feed heater, 158 degrees. The indicator springs used were in all cases 60 pounds per inch for high pressure and 20 pounds for low pressure.

MERCHANT SHIPS.

A Mammoth New Atlantic Liner.—There is under construction in the Belfast yard of Harland & Wolff an immense passenger steamer for the Hamburg-American Line which has many points of interest entirely aside from its size. A principal feature is the fact that this ship is to be fitted with a combination of reciprocating and turbine machinery, there being provided three screws, of which the two outer ones are actuated each by a quadruple-expansion steam engine, while the center shaft is turned by a low-pressure steam turbine, the steam for which is given by the exhaust from the piston engines. The total horsepower will be somewhere in the neighborhood of 30,000, giving an estimated sea speed of 20 knots. It is reported that a swimming tank, 25 by 75 feet, and a tennis court are to be provided.

The principal dimensions of this ship show a length over all of 804 feet, a length between perpendiculars of 758 feet, a beam of 88 feet, and a depth to the upper deck of 63 feet 9 inches. It will be noted that the length over all exceeds that of the *Lusitania* and *Mauretania* by about 15 feet; the length between perpendiculars is 2 feet short of the Cunarders; the beam is the same, and the depth is more than 3 feet greater. The ship has thirteen watertight bulkheads and five complete decks in the hull, running from bow to stern.

Some of the principal scantling members have been given as follows by Schiffbau:

Flat keel, $1\frac{1}{4}$ inches; garboard strake, $1\frac{1}{16}$ inches; bottom strakes, $\frac{15}{16}$ inch; bilge strakes, 1 inch, 1 inch and $1\frac{1}{16}$ inches; side plates, $\frac{15}{16}$ inch; sheer strake, 1 inch; center-line vertical keel, $\frac{15}{16}$ inch; double-bottom horizontal center plate, $\frac{11}{16}$ inch; double-bottom side plates, $\frac{9}{16}$ inch; upper-deck stringer

plate, $\frac{15}{16}$ inch; inner stringer plate, $\frac{3}{4}$ inch; middle-deck stringer plate, $\frac{3}{4}$ inch; other stringer plates, $\frac{9}{16}$ inch; deck plating on the upper deck, $\frac{9}{16}$ inch; on the middle deck, $\frac{7}{16}$ inch; on the other decks, $\frac{3}{8}$ inch. The depth of the double bottom is given as 5 feet 4 inches, and the frame spacing as 36 inches. The frames are channels measuring 10 by 4 by 4 by $\frac{21}{32}$ inches. The deck beams on the upper deck are channels 8 by 4 by 4 by $\frac{1}{2}$ inches. The deck beams on the middle, lower and orlop decks are channels 10 by $3\frac{1}{2}$ by $3\frac{1}{2}$ by $\frac{1}{2}$ inches. Hold beams measure 10 by 4 by 4 by $\frac{1}{2}$ inches.

The Cunard Steamship Mauretania.—Our description of the *Lusitania* will apply almost equally well to her sister ship. The difference between the two ships from a fundamental point of view is slight, but a number of minor differences, and particularly differences in the decorations, have been made. The present ship was built by Swan, Hunter & Wigham Richardson, Limited, Newcastle-on-Tyne, and has been supplied with propelling machinery by the Wallsend Slipway & Engineering Company, Limited. The general dimensions are as follows: Length over all, 790 feet; length between perpendiculars, 760 feet; breadth, molded, 88 feet; depth, molded, 60 feet 6 inches; gross tonnage, 33,200; mean load draught, 33 feet 6 inches; corresponding displacement, in tons, 38,000; designed horsepower, 68,000; contract speed (one round trip per year), 24.5 knots.

It is thus seen that the vessel exceeds the *Lusitania* in depth by $1\frac{1}{2}$ inches, and in gross tonnage by 700. Provision is made for 2,165 passengers and a crew of 938, making a total of 3,103. Of the passengers, 563 first-class are carried in 253 staterooms, 35 of which are each for one passenger only; 464 second-class passengers are carried in 133 staterooms; while the third-class, 1,138 in number, are carried in 278 rooms with from two to eight berths each. The seating accommodation of the various dining saloons are 470 in the first-class, 251 in the second-class and 520 in the third-class.

While externally and internally the *Lusitania* and the *Mauretania* are similar in the main features of their design and ar-

rangement, there are differences in detail that are readily apparent. What most strikes one on approaching the *Mauretania* is the difference in the overhead deck erections. Where the *Lusitania* has square trunks with hinged covers for the ventilation of the stokeholds, the newer ship has wide-mouthed ordinary cowls, and, as they are a good deal higher, they somewhat enhance the appearance of the vessel. Then, again, the promenade deck and also the boat deck above project over the shelter deck by about two feet for nearly three-fourths of the length of the vessel. This, on the two decks on which this arrangement has been carried out, makes a very appreciable addition to the free space for promenading on both sides of the ship.

Internally, while the arrangement of the various apartments is almost identical in the two vessels, there is an entire contrast in the architectural treatment and decoration. Speaking broadly, the prevailing aspect of the public rooms in the *Lusitania* is one of lightness and brightness, the outcome of a liberal use of light-colored enamels and gilt. In the *Mauretania*, on the other hand, costly woods in their natural colors are relied upon for decorative effect, producing what might be described as an impression of handsomeness and substantiality. Both schemes of decoration are successful in their own way, and preference for the one or the other will differ according to the taste or temperament of the individual. The dining saloon and upper saloon in the *Mauretania* are in oak in the Francis I style, beautifully carved. In the main entrance hall and staircase the design is Italian renaissance, carried out in French walnut, and the same style in the same wood, with the addition of satinwood inlay, is used with fine effect in the smoking room. The library is done in sycamore of a beautiful grey shade, and is furnished in Louis XVI style, and the same style is carried out in the lounge and music room in mahogany, with large tapestry panels flanked by duplicate pillars of grained marble. The staterooms and regal suites of rooms are variously treated in Adams, Georgian and Sheraton styles.

Equal taste, and not much less expenditure, have been be-

stowed on the second-class accommodation, in which the dining saloon is in oak after the Georgian period, the drawing room in maple, in a modified Louis XVI style, the smoking room in mahogany, and the lounge and entrance hall in polished teak. A new feature in the second-class accommodation is a large deck shelter, which must add greatly to the comfort of the passengers in cold or stormy weather. In their degree, the third-class passengers have also been liberally dealt with, both in their dining saloon and sleeping quarters, the latter being exceptionally large and airy, while the former is nicely finished in polished ash.

The ship is propelled by steam turbines of Parsons type. The total heating surface of the twenty-five boilers (twenty-three double-ended and two single-ended cylindrical) is 159,000 square feet (3.65 acres); the grate surface is 4,060 square feet, and the boilers are fitted for Howden's forced draft. The boilers have shells of high-tensile steel, and discharge the products of combustion into four elliptical funnels with outer casings measuring 26 feet fore-and-aft and 19 feet athwartships. The 192 furnaces are of the Morison suspension type, built by the Leeds Forge Company. Each furnace has a separate combustion chamber.

The turbine rotor wheels, which are usually two in number, one at each end of the drum, are supplemented in this case by two inner wheels to stiffen the drum in its great length. The line shafting has a diameter of 22 inches, but in the bearings it is increased to 36 and 52 inches, a conical section being interposed. The bearings are about 5 feet in length. The propellers have a pitch of about 16 feet, and operate at a slip of about 15 per cent.

The disks and gudgeons, as well as the shafts and drums of the turbines, were made of Whitworth fluid-pressed steel, all stiffeners being solid and integral with the drums, with the idea of getting maximum strength and rigidity with minimum weight, and also to avoid distortion or straining in heating up or cooling down. The high-pressure drums are 96 inches in diameter, and the rotors, including bearings, are

45 feet 8 inches long. The blades, in eight stages, vary from 2½ to 12 inches in length. The low-pressure drums are 140 inches in diameter and 48 feet 2 inches long, with eight stages of blades, varying from 8 to 22 inches in length. The astern turbine drums are 104 inches in diameter and 30 feet 1 inch long, with blades from 2 to 8 inches, in eight stages.

In the rotors and lower half casings the usual method of fitting blades has been followed. This consists in first fitting a fixed stop piece, which sets the correct blade angle. This is held in position in the rotor groove by means of a steel wedge. The first blade and packing piece are then inserted, and, after a number are in position, the set is tapped up with a hammer and tool and afterwards calked. The blades are held together and stiffened by wire binding, the brass wire being fitted into a small saw-cut near the upper end of each blade, and passing on to the successive blades in turn. This forms a brass ring extending around the circle of blades near their upper end. In longer blades two such rings are employed, and in the 22-inch blades of the low-pressure turbines are three sets of wires. A fine copper wire is lashed around each blade and its brass binding wire, to hold everything solidly in place, and the entire connection brazed over by means of silver solder.

The turbine blading in the upper half of the casings is on the Willans & Robinson system. "The blade roots are fitted into two solid half rings, which are accurately divided off by machine cuts, and thus give uniform adjustment to the blade pitches and angles throughout. At the outer ends or tips the blades fit, by means of a tang, into a channel-shaped brass ring or shroud. The blading is completed independently in two or more sections before being fitted into the casing. The channel-shaped shroud can be adjusted to reduce the tip clearance, and, should fouling occur, the channel ring would wear away and give its own clearance, or would, perhaps, bend over, thus protecting the blades and eliminating the danger of blade stripping. It will be noted that in this system no separate packing pieces are required, and that the brass-wire

binding and upper wire lacing are required only in the case of the very long blades near the low-pressure end of the low-pressure turbines."*

The numerous pumps and other steam auxiliaries include a large number by G. & J. Weir, Limited, Cathgart, Glasgow. Others are by W. H. Allen, Son & Company, Limited, Bedford; J. H. Carruthers & Company, Limited, Glasgow; Clarke, Chapman & Company, Limited, Gateshead-on-Tyne, and Brown Brothers, Newcastle. In addition, there are pumps by the Liverpool Engineering Company in connection with the refrigerating plant, and pumps by J. Stone & Company, Deptford, London, for the Stone-Lloyd system of watertight bulkhead doors. Heating and ventilating is on the thermo-tank system, by the Thermo Tank Ventilating Company, of Glasgow. Electric lighting is provided by four turbo-generators, each of 375 kilowatts, supplied by C. A. Parsons & Company, Limited, Heaton-on-Tyne.

The stern frame and bracket casting for the two inner propellers is a mammoth piece of work by the Darlington Forge Company, Limited, the weight being 104 tons. The strut frames for the outer propellers weigh together 48 tons, while the rudder, with an area of 420 square feet, weighs 63½ tons. The stem bar and stem foot piece are respectively an ingot-steel forging weighing 8½ tons, and a cast-steel member of 1½ tons.

There are twelve transverse bulkheads, and intermediate wing bulkheads are fitted in the side bunkers, dividing them into spaces about 40 feet long. Including the double bottom there are altogether 175 watertight compartments. For a distance of nearly 350 feet alongside the boilers the ship has a complete inner and outer skin, not only on the bottom, but also on the sides, being in this respect similar to warship construction.

The maiden trip (Nov. 16 to 22) of this ship was unfortunate by reason of tremendous seas due to a heavy gale. A spare anchor was torn loose, and it is estimated that the total

* J. W. Sothern: "The Marine Steam Turbine."

loss in time occasioned by this and the storm aggregated seventeen hours. As it was, however, the distance of 2,780 nautical miles between Daunt's Rock and Sandy Hook lightship was covered in 5 days 5 hours and 10 minutes, at an average of 22.21 knots. On one single day, however, the ship covered 624 nautical miles, which makes the day's run at the rate of 24.99 knots. This is six miles more than was covered by the *Lusitania* in her highest day's run, a few weeks previous, and makes a new record. During this run the *Mauretania's* revolutions averaged 172 per minute, and did not exceed 180. On her trial trip, however, the revolutions reached as much as 194 per minute, the average speed for more than 1,200 miles having been a little over 26 knots. During a portion of this time the speed was 26.75 knots, and one run of 300 miles is stated to have shown no less than 27.36 knots, by far the highest speed ever shown by any vessel over 300 feet in length.—"International Marine Engineering."

A Large French Steamer.—The steamship *Malte*, built to the order of La Compagnie des Chargeurs Réunis, of Paris and Havre, by Swan, Hunter & Wigham Richardson, Wallsend-on-Tyne, is the first merchantman of the French fleet built especially for an all-around-the-world service.

This steamer has the following particulars: Length between perpendiculars, (147.21 meters) 483 feet; breadth, (16.95 meters) 55 feet 8 inches; depth, (10.36 meters) 34 feet; draught, full loaded, (7.32 meters) 24 feet; gross tonnage, 8,321 tons; net tonnage, 5,606 tons; deadweight capacity, 9,500 tons; indicated horsepower, 5,800; mean full speed on trials, 14.5 knots.

This steamer is given the highest class in the French Veritas. She has been built on the deep frame and girder system, and is rigged as a two-masted schooner. There are three decks worked from stem to stern; above the main deck there is a top-gallant forecastle, 55 feet in length, in which the crew, the petty officers and stewards are berthed.

Amidships there is a long bridge house, 182 feet in length,

in which accommodations are provided for fifty-seven first-class passengers in very roomy cabins; the staterooms being situated in the bridge, on the bridge in deck houses, and also in deck houses above that again. The dining saloon is at the front end of the bridge, and a drawing room and a smoking room are also provided, with several "en suite" rooms. The furnishing and outfit are severely plain, but they are especially suited for hot climates. Accommodations are also provided for steerage passengers, who will be located in the first 'tween deck. Aft there is a full poop, with accommodations for officers and a few passengers; the poop has a total length of 33 feet 6 inches.

The ship is divided into eleven watertight compartments, and a complete cellular double bottom extends from end to end. The total capacity of water in this double bottom is 1,322 tons; fore and aft in peaks 210 tons, and in special holds amidships 1,982 tons of water might be shipped; the total water carried on ballast trim therefore is 3,514 tons, which allows good seaworthiness to the ship for running long distances on ballast.

The main 'tween decks are very high, which allows the carrying of horses or cattle. The handling of the cargo has been specially well studied. There are not less than fourteen powerful winches, with latest type of derrick accommodations; the most powerful winch can lift 40 tons, and the smallest 5 tons. Everything has been designed for a quick discharging or loading of the cargo.

The ship is fully equipped with the most modern conveniences, including electric light and a complete refrigerating plant on Hall's CO_2 system, which allows the ship to carry perishable cargo.

The vessel is propelled by twin screws, driven by two engines of the triple-expansion, three-cylinder type, which, at ninety revolutions per minute, have developed an average of 5,800 indicated horsepower. The contract conditions as regards speed were somewhat severe, the vessel having to run for a 4-hour full-power trial, and subsequently a 24-hour con-

sumption trial. On September 2 last, during the former, the mean indicated horsepower developed considerably exceeded the guaranteed power; the 24-hour trial was equally successful, the vessel attaining a mean speed of over 14½ knots, the guaranteed speed being only 13½ knots.

The main engines have cylinder diameters of 25½, 43 and 70 inches, and the stroke is 48 inches. The main and auxiliary engines receive steam from six cylindrical boilers of the usual type, being 11 feet 9 inches in length and 15 feet 3 inches in diameter; there are 18 furnaces. The total surface of grate is 366 square feet, and the heating surface 15,660 square feet, giving a ratio of 42.8 to 1. The boilers are fitted with Howden's forced-draft system. The normal pressure in the boilers is 200 pounds per square inch.

The steamer came to St. Nazaire with 9,000 tons of coal and was measured by customs officials; afterwards she made her official trials for the "subsidy," and then took 5,000 tons of patent fuel for the Saigon dockyard. On leaving St. Nazarre she went to Antwerp, then to Dunkirk, and has left for her maiden trip *via* Suez Canal, Singapore, Hong Kong, Shanghai and other Eastern ports; thence *via* the Pacific to various ports on the west and east coast of South America, and subsequently to the United Kingdom, France and Antwerp. Such a trip is expected to last 240 days.—"International Marine Engineering."

Japan's First Turbine Steamer.—The first turbine steamer for the mercantile marine of Japan has been built by William Denny & Brothers, Dumbarton. The steel turbine steamer *Hirafu Maru* was the first of two vessels ordered by the Japanese States Railway for special service in the Tsugaru Straits. The launch was noteworthy as marking the introduction of the turbine to Japan and also because the ceremony was purely Japanese.

The ship has a length of 280 feet; breadth, 35 feet, and depth, 21 feet 6 inches. She has been built under special survey of Lloyd's register, and in accordance with the requirements of the British Board of Trade and of the Teishinsho rules. The

turbine machinery, which is supplied by Denny & Brothers, was designed to maintain a mean speed of 18 knots. On trial in the Firth of Clyde the speed obtained was 19.08 knots.

There is accommodation for first, second and third-class passengers. The first-class passengers are located in a deck house on the awning deck. Large cabins, having Pullman berths, are provided for ladies and gentlemen, in addition to the ordinary staterooms, and a special stateroom on the boat deck. The first-class dining saloon is designed in the Louis XVI style, and has a very high roof, the upper paneling of which is divided in leaded glass panels representing ancient shipping and other marine subjects. The ceiling, which is tastefully paneled like the rest of the apartment, is finished in white and gold. The sideboards and doors are of same design, the latter having the company's crest worked in leaded glass. The main vestibule is framed in light oak, dull polished. The second-class passengers are located in a deck house abaft the boiler, both classes having sheltered promenades underneath the boat deck, in addition to which the first-class passengers have a promenade on the boat deck itself. The third-class passengers are accommodated in Japanese style at the after end of the main deck. Forward of this is accommodation for officers and engineers and the crew.

A large room is provided for mails, with suitable accommodation for the mail officers. Ample bathing accommodation is provided for all classes, as customary in Japanese vessels. The firemen and cooks, etc., are accommodated on the lower deck, which is fitted in the forward hold. Provision is made for a limited amount of cargo in the main and after holds.

The vessel is fitted with a balanced rudder of the builders' special type, actuated by a steam and hand-steering gear controled from the flying bridge. The anchors, which are of the stockless pattern, are worked by powerful steam windlass, while a warping winch aft enables the vessel to be easily handled in harbor.—"International Marine Engineering."

BERECHNUNG UND KONSTRUKTION DER SCHIFFSMASCHINEN UND KESSEL. By DR. G. BAUER, Engineer-in-Chief of the Vulcan Works, Stettin. 3d edition. Munich and Berlin: R. OLDENBOURG, 1908.

This, the third German edition of Dr. Bauer's well known work on reciprocating marine engines and boilers, is of the same high character as the preceding editions. It has been enlarged by the addition of valuable information both in the text and in illustrations, and is, in all respects, an excellent work.

OBITUARY.

JACKSON McELMELL, CHIEF ENGINEER (REAR ADMIRAL) U. S. N., RETIRED.

By W. M. McFarland, Member.

On May 31, 1908, there passed away one of the most beloved officers of the Navy and one whose influence on the younger officers of the Engineer Corps was all for good and far reaching in its effects. It is probable that Admiral McElmell was almost the only officer in the Service who knew personally every officer in the Engineer Corps, as all of them had been before him at least once and most of them twice to be examined for promotion.

Admiral McElmell was born in Philadelphia June 4, 1834, the oldest son of James and Katherine McElmell. After a preliminary education in the public and private schools of Philadelphia he attended Holy Cross College at Worcester, Mass., from which he received the degree of Master of Arts. With a natural aptitude for mechanics and a fondness for the sea, he decided to become a naval engineer. As the technical schools are all of more recent date than this period in his life, he secured the technical experience needed by spending two years with the well known ship and engine building establishment of Neafie & Levy, of Philadelphia. As a further training, he served for a short time on a merchant steamer, and then, in August, 1855, entered the Navy as Third Assistant Engineer, his first duty being on the Coast Survey Steamer *Hetzel*, where he assisted in the survey of the sounds of North Carolina.

In 1857 he was fortunate enough to be ordered to the Steamer *Niagara*, which, as is well known, laid the first At-

lantic cable. In this work Admiral McElmell had quite an important part, as he was specially detailed to look after the machinery for the laying of the cable. For his share in the work he later received a gold medal from the New York Chamber of Commerce. In 1858 he was attached to the *Memphis*, one of the "mosquito fleet," which was sent to demand reparation from Paraguay for firing on an American vessel.

After further routine sea duty we find him as First Assistant Engineer on the *Powhatan* at the beginning of the Civil War. He was engaged in active sea duty from the beginning to the end of the great conflict and took part in a number of important engagements; among these were the attack on Forts Jackson and St. Philip, guarding the approaches to New Orleans, and the bombardment of the batteries at Vicksburg in June, 1862. From 1863 to 1865 he was Chief Engineer of the *Richmond*, and during that time participated in the memorable battle of Mobile Bay under Admiral Farragut.

His service after the Civil War comprised the usual alternation of sea and shore duty, much of which was necessarily of a routine character, owing to the almost complete stagnation in our naval progress at that time. However, he had an active part in the early work of developing the League Island Navy Yard. His last sea service was as Fleet Engineer of the North Atlantic Station, on the *Tennessee* and on the *Richmond*, ending in December, 1887.

During previous shore duty he had been a member of the Naval Engineers' Examining Board, and on March 6, 1888, he was ordered to duty as President of that Board and continued as such until he was retired in June, 1896. During the war with Spain and for a short time afterwards he was again placed on active duty and detailed to this same duty for about a year, during which time he not only examined the regular engineers who came up for promotion but also the great majority of those who were appointed volunteer engineers for the war.

This work on the Examining Board was undoubtedly the most important part of his naval career. To be an ideal examiner is rather difficult. Duty to the Government requires a rigid test of the candidate's ability, while tender-heartedness might lead to undue leniency. Admiral McElmell was one of the few who were able to maintain the golden mean. Every man who appeared before him knew that he must be thoroughly prepared or he would not be passed, but on the other hand he knew that there would be no attempt to confuse or discourage him, and that the strict examiner was at the same time a sympathetic friend. The result was that every man was stimulated to do his very best, both in preliminary preparation and in his actual work before the Examining Board.

Admiral McElmell had that fine *esprit de corps* (which unfortunately has not been the characteristic of all senior officers in our Service) which made him feel that, although discipline required recognition of difference in rank, junior officers were still brother officers, and when duty had terminated and social relations could be considered he was a charming friend. The writer and the many others who were examined by him will never forget his personal courtesies extended outside of the examining room. Indeed, so great was the affection which they all entertained for him that since his retirement, whenever in Philadelphia, they made it a point to call and spend a social hour with him.

His long detail as President of the Examining Board is a sufficient testimonial of his high professional attainments, but besides being an able engineer, he was a man of broad general culture and literary attainments. As a companion and friend he was altogether delightful, and all who had the privilege of his friendship will for many a day feel a keen regret at the thought that no longer can they enjoy the pleasure of association with him.

In 1869 Admiral McElmell married Miss Mary Thomas and two sons were born to them, but his children died in infancy and his wife soon followed them, so that for a long

time his home had been with a widowed sister and her family and his brother, Mr. Thomas A. McElmell, who was formerly an officer in the Navy. He was a member of the Union League and United Service Club of Philadelphia, the Pennsylvania Historical Society and the Catholic Club of New York. He was for a time Senior Vice-Commander of the Pennsylvania Commandery of the Loyal Legion, of which he was one of the earliest members. When retired he had the rank of Commodore, but by the Act of Congress of June 29, 1906, he was advanced to be a Chief Engineer with the rank of Rear Admiral.

It is not given to every man to make himself famous by some great exploit. While the epochs of history are marked by the men who were heroic, the vast bulk of the world's work is done by those who are faithful in the performance of the duty, however modest, which lies right at hand. And in this work is he not great who does all he can to make those around him happy and always lends a helping hand? Such a man, clean, upright and noble, was Jackson McElmell.